



United States
Department of
Agriculture



United States
Department
of the Interior



Natural
Resources
Conservation
Service



National Park
Service

Soil Survey of Sunset Crater Volcano National Monument, Arizona



How To Use This Soil Survey

General Soil Map

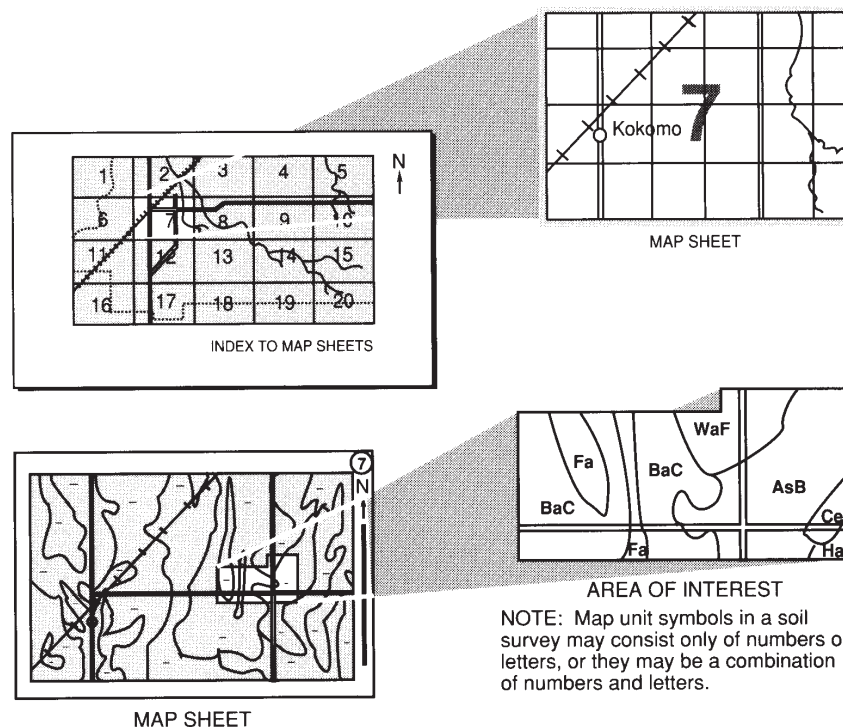
The general soil map, which is a color map, shows the survey area divided into groups of associated soils called general soil map units. This map is useful in planning the use and management of large areas.

Detailed Soil Map

The detailed soil map can be useful in planning the use and management of small areas.

Locate your area of interest on the map sheet. Note the map unit symbols that are in that area. Go to the **Contents**, which lists the map units by symbol and name and shows the page where each map unit is described.

The **Contents** shows which table has data on a specific land use for each detailed soil map unit. Also see the **Contents** for sections of this publication that may address your specific needs.



National Cooperative Soil Survey

This soil survey is a publication of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service has leadership for the Federal part of the National Cooperative Soil Survey.

Major fieldwork for this soil survey was completed on August 31, 2011. Soil names and descriptions were approved on August 31, 2011. Unless otherwise indicated, statements in this publication refer to conditions in the survey area in 2011. This survey was made cooperatively by the Natural Resources Conservation Service and the National Park Service.

The soil map in this survey may be copied without permission. Enlargement of this map, however, could cause misunderstanding of the detail of mapping. If enlarged, the map does not show the small areas of contrasting soils that could have been shown at a larger scale.

Literature Citation

The correct citation for this survey is as follows:

United States Department of Agriculture, Natural Resources Conservation Service, and United States Department of the Interior, National Park Service. 2014. Soil survey of Sunset Crater Volcano National Monument, Arizona. (Accessible online at: http://soils.usda.gov/survey/printed_surveys/)

Cover Caption

Sunset Crater as seen from the northwest at the top of an unnamed cinder cone inside Sunset Crater Volcano National Monument, Arizona. Map unit 26 (Kana`a-Cinder land complex, 15 to 60 percent slopes) is on the low-lying older cone in the foreground. This older cone has been buried with cinders and ash from the more recent Sunset Crater explosion. Wind has driven ash along the inside surface of the cone in a covering of ripples. Ripples occur where sand size grains form small heaps when winds flow predominantly from one direction. Some of the moving sands will infiltrate into the first few centimeters of the soil profile during summer monsoons. The nonvegetated areas are Cinder land. Where trees and bushes have gained a foothold, the influx of organic material has converted the Cinder land to soils classified in the Kana`a series. In the background, on the side slopes of Sunset Crater, is map unit 20 (Cinderhill-Blackash complex, 15 to 60 percent slopes). Cinderhill and Blackash soils have incorporated a larger amount of ash into their profiles than Kana`a soils and also support more dense vegetation.

Additional information about the Nation's natural resources is available online from the Natural Resources Conservation Service at <http://www.nrcs.usda.gov/>.

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Preface

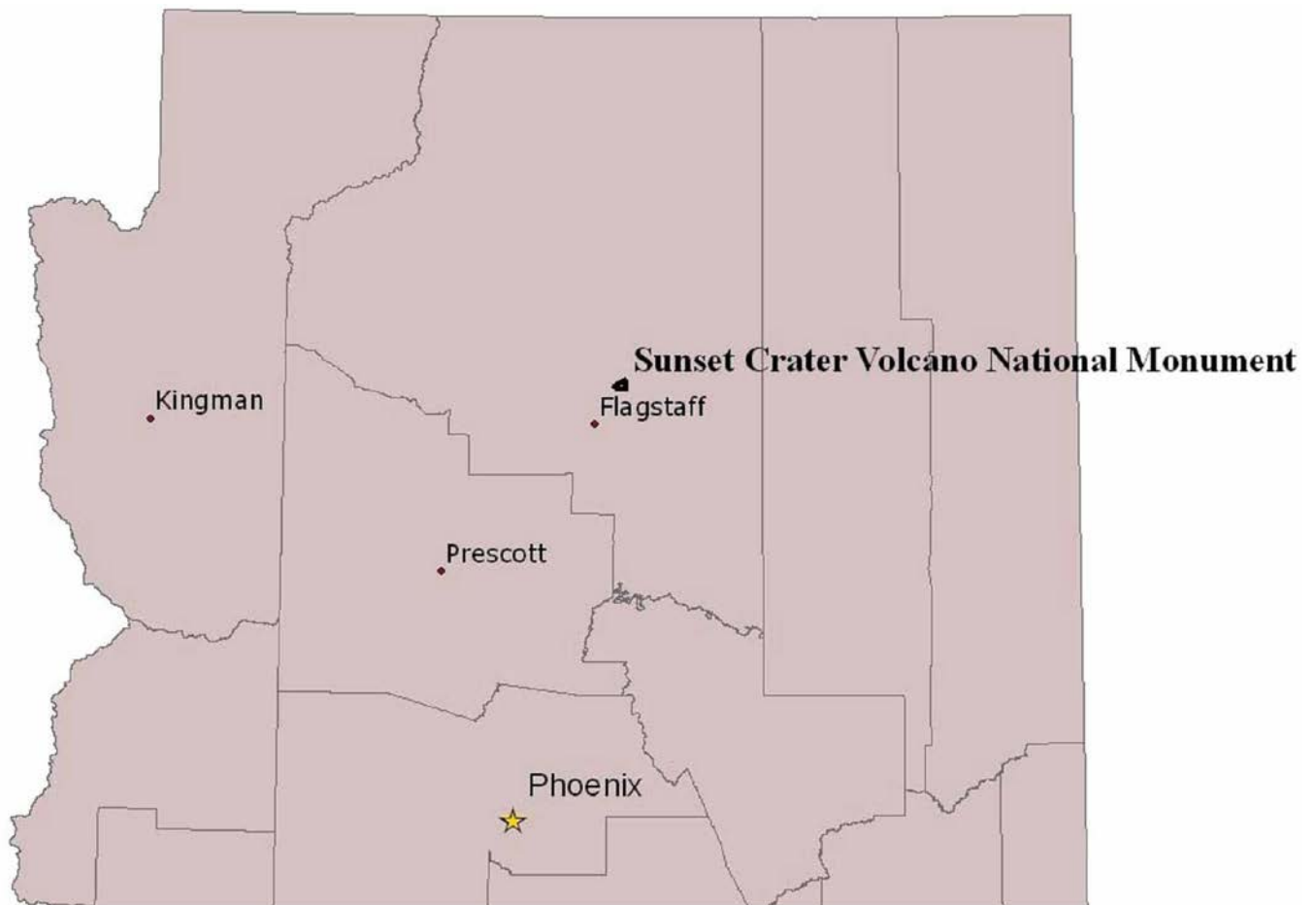
This soil survey was developed in conjunction with the National Park Service's Soil Inventory and Monitoring Program and is intended to serve as the official source document for soils occurring within Sunset Crater Volcano National Monument, Arizona.

This soil survey contains information that affects current and future land use planning in the park. It contains predictions of soil behavior for selected land uses. The survey highlights soil limitations, actions needed to overcome the limitations, and the impact of selected land uses on the environment. It is designed to meet the needs of the National Park Service and its partners to better understand the properties of the soils in the park and the effects of these properties on various natural ecological characteristics. This knowledge can help the National Park Service and its partners to understand, protect, and enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. The information in this report is intended to identify soil properties that are used in making various land use or land treatment decisions. Statements made in this report are intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are shallow to bedrock. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

These and many other soil properties that affect land use are described in this soil survey. The location of each map unit is shown on the detailed soil map. Each soil in the survey area is described, and information on specific uses is given. Help in using this publication and additional information are available at the local office of the Natural Resources Conservation Service or the park office for Sunset Crater Volcano National Monument.



Location of Sunset Crater Volcano National Monument in Arizona.

Soil Survey of Sunset Crater Volcano National Monument, Arizona

By James M. Harrigan, Natural Resources Conservation Service

Fieldwork by James M. Harrigan and Michael W. Burney, Natural Resources Conservation Service

Ecological site assessment by Jennifer M. Puttere, Natural Resources Conservation Service

United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the United States Department of the Interior, National Park Service

SUNSET CRATER VOLCANO NATIONAL MONUMENT lies within the State of Arizona, 20 miles northwest of Flagstaff. Established in 1930 to preserve and protect Sunset Crater and surrounding lands, the park comprises approximately 3,040 acres. It consists of cinder cones and lava flows from recent eruptions. The entire extent of the park is volcanic in origin. The park covers a small part of the San Francisco Volcanic Field. (See [Sunset Crater Volcano National Monument 3D Map](#) accompanying this report.)

The surrounding area adjoining Sunset Crater is managed by the Coconino National Forest. The Forest Service manages campgrounds near Bonito Park to the west, picnic grounds to the northeast at Painted Desert Vista, a hiking trail to the top of O'Leary Peak to the north, and also the Cinder Hills Off Road Vehicle Area to the southeast.

Sunset Crater Volcano National Monument has a Visitor's Center, near the park's west entrance, which is operated by the Park Service. The park also has nature trails. Lenox Crater Trail provides an opportunity to climb a cinder cone. It is a steep trail 1 mile in length over loose cinders. From here one can also view the Bonito Lava Flow. Further east is Lava Flow Trail, a self-guided loop trail 1 mile in length that provides views of volcanic squeeze ups, spatter cones (also called hornitos), and areas of lava tubes. The original trail to the top of Sunset Crater has been closed due to massive erosion. Continuing east along the road, the Cinder Hills Overlook, near the east entrance, offers a view of Sunset Crater from the northeast as well as views of Double Crater and other craters in the Cinder Hills Off Road Vehicle Area. The road continues beyond the east entrance along a second lava flow associated with Sunset Crater, the Kana'a Lava Flow, to Wupatki National Monument.

Much of the park is accessible by vehicle. U.S. Route 89 runs near the western boundary, near the city of Flagstaff, on its way north to Cameron and the Navajo Reservation. The paved road from U.S. Route 89 enters Sunset Crater Volcano National Monument from the west and continues through the park to the east, where the road turns north and heads to Wupatki National Monument.

Descriptions, names, and delineations of soils in the survey do not fully agree with some of the soil maps for adjacent soil survey areas. The differences are the result

of mapping intensity, the availability of more recent technology for soil mapping, modifications in series concepts, or extent of soils within the survey.

General Nature of the Park

This section briefly discusses the history, physiography, and climate of the survey area.

History

Sunset Crater National Monument was established by President Herbert Hoover on May 26, 1930, to protect the area's geologic formations. In 1928, a Hollywood film company planned to detonate large quantities of explosive on the side of Sunset Crater in order to create an avalanche for Zane Gray's motion picture "Avalanche." Public outcry over this plan led in part to the proclamation of Sunset Crater National Monument. In 1990, the name of the park was changed to Sunset Crater Volcano National Monument to distinguish the origin of the crater from Meteor Crater (about 40 miles to the east).

Physiography

Sunset Crater Volcano National Monument lies within the San Francisco Volcanic Field. This volcanic field remains over a hot spot. More recent activity has occurred on the east end of the volcanic field to the north and to the south. (See [Sunset Crater Volcano National Monument 3D Map](#) accompanying this report.)

Climate

The climate of the survey area is highly variable with moderately severe extremes. Often there is snow cover in winter months that may be as much as 100 inches deep. Spring tends to be warmer and windier. Monsoonal rain patterns typically begin in July and last into late September. Brief heavy rains and thunderstorms may occur on a nearly daily basis.

Table 1 gives data on temperature and precipitation for the survey area as recorded at Sunset Crater Volcano National Monument, Arizona, in the period 1969 to 2013. Table 2 shows probable dates of the first freeze in fall and the last freeze in spring. Table 3 provides data on the length of the growing season.

In winter, the average temperature is -1.6 degrees C and the average daily minimum temperature is -10.3 degrees C. The lowest temperature on record, which occurred at Sunset Crater Volcano National Monument on February 26, 1986, was -33 degrees C. In summer, the average temperature is 17.2 degrees C and the average daily maximum temperature is 27.4 degrees C. The highest temperature, which occurred at Sunset Crater Volcano National Monument on June 25, 1988, was 37.2 degrees C.

Growing degree days are shown in table 1. They are equivalent to "heat units." During the month, growing degree days accumulate by the amount that the average temperature each day exceeds a base temperature (50 degrees F). The normal monthly accumulation is used to schedule single or successive plantings of a crop between the last freeze in spring and the first freeze in fall.

The average annual total precipitation is 42.65 centimeters. Of this, 26.82 centimeters, or about 63 percent, usually falls in April through October. The growing season for most crops falls within this period. The heaviest 1-day rainfall during the period of record was 6.53 centimeters at Sunset Crater Volcano National Monument on December 5, 1992. Most thunderstorms occur between July and September.

The average seasonal snowfall is 151.13 centimeters. The greatest snow depth at any one time during the period of record was 81 centimeters, recorded on January 23,

2010. On an average, 126 days per year have at least 2.54 centimeters of snow on the ground. The heaviest 1-day snowfall on record was 71.1 centimeters, recorded on December 14, 1987.

How This Survey Was Made

This survey was made in conjunction with the National Park Service's Soil Inventory and Monitoring Program to provide soil assessment and to manifest an information guide that can be implemented for use and management. A scoping meeting was held in 2010 with park staff to identify soil resource and information needs. Of particular importance is the relationship between soil type and plant communities to climatic regimes and landforms. Also of interest is possibility of past and present water tables.

During the soil survey, ecological site and soil component relationships were observed. Soil-site correlation concepts were established to help in designing the map units. Soil and plant specialists tested the concepts during mapping and collected field documentation at numerous points across the landscape.

The information includes a description of the soils and miscellaneous areas and their location and a discussion of their suitability, limitations, and management for specified uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of native plants; and the kinds of bedrock. They dug many holes to study the soil profile, which is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

The soils and miscellaneous areas in the survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

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considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units).

Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil Taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they delineated the boundaries of these bodies on digital imagery and identified each as a specific map unit.

General Soil Map Units

The general soil map in this publication shows broad areas that have a distinctive pattern of soils, relief, and drainage. Each map unit on the general soil map is a unique natural landscape. Typically, it consists of one or more major soils or miscellaneous areas and some minor soils or miscellaneous areas. It is named for the major soils or miscellaneous areas. The components of one map unit can occur in another but in a different pattern.

The general soil map can be used to compare the suitability of large areas for general land uses. Areas of suitable soils can be identified on the map. Likewise, areas where the soils are not suitable can be identified.

Because of its small scale, the map is not suitable for selecting a site for a road or building or other structure. The soils in any one map unit differ from place to place in slope, depth, drainage, and other characteristics that affect management.

1—Cinderhill-Kana`a-Sunsetcrater association

Very deep, gently sloping to moderately steep, well drained soils that formed from cinder cones

Setting

Ecological site associations: Cindery-Ashy Upland 17-22" p.z. and Cinder Cones 17-22" p.z.

Dominant vegetation: Ponderosa pine and sand bluestem

Landscape: Colorado Plateau

Landform setting: Cinder cones

Elevation: 6,795 to 8,039 feet (2,071 to 2,450 meters)

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Slope range: 1 to 60 percent

Composition

Extent of the map unit in the survey area: 48.5 percent

Extent of the components in the map unit:

Cinderhill soils—29 percent

Kana`a soils—26 percent

Sunsetcrater soils—22 percent

Minor components—23 percent (Cinder land and Blackash soils)

Component Descriptions

Cinderhill

Depth class: Very deep

Drainage class: Well drained

Geomorphic position: Cinder cones

Parent material: Tephra

Slope: 15 to 60 percent

Ecological site ID: R039XA141AZ

Kana`a

Depth class: Very deep
Drainage class: Well drained
Geomorphic position: Cinder cones
Parent material: Tephra
Slope: 15 to 60 percent
Ecological site ID: R039XA143AZ

Sunsetcrater

Depth class: Very deep
Drainage class: Well drained
Geomorphic position: Cinder cones and tephra deposits
Parent material: Tephra
Slope: 1 to 60 percent
Ecological site ID: R039XA141AZ

2—Kana`a-Cinderhill association

Very deep, nearly level to gently sloping, well drained soils that formed from tephra deposits

Setting

Ecological site association: Cindery-Ashy Upland 17-22" p.z.
Dominant vegetation: Apache plume and ponderosa pine
Landscape: Colorado Plateau
Landform setting: Tephra deposits
Elevation: 6,905 to 7,300 feet (2,105 to 2,225 meters)
Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest
Slope range: 1 to 15 percent

Composition

Extent of the map unit in the survey area: 20.6 percent
Extent of the components in the map unit:
 Kana`a soils—47 percent
 Cinderhill soils—39 percent
 Minor components—14 percent (Blackash soils and Cinder land)

Component Descriptions

Kana`a

Depth class: Very deep
Drainage class: Well drained
Geomorphic position: Tephra deposits
Parent material: Tephra deposits
Slope: 1 to 15 percent
Ecological site IDs: R039XA141AZ and R039XA143AZ

Cinderhill

Depth class: Very deep
Drainage class: Well drained
Geomorphic position: Tephra deposits
Parent material: Tephra deposits
Slope: 3 to 15 percent
Ecological site ID: R039XA141AZ

3—Lava flows-Lithic Ustorthents-Blackash association

Shallow to very deep, level to gently sloping, well drained soils that formed from tephra over lava flows

Setting

Ecological site associations: Cinders-Lava Flow Upland 17-22" p.z. and Cinder Cones 17-22" p.z.

Dominant vegetation: Apache plume, ponderosa pine, and buckwheat

Landscape: Colorado Plateau

Landform setting: Lava flows and lava fields

Elevation: 6,830 to 7,025 feet (2,082 to 2,141 meters)

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Slope range: 2 to 15 percent

Composition

Extent of the map unit in the survey area: 30.2 percent

Extent of the components in the map unit:

Lava flows—52 percent

Lithic Ustorthents—12 percent

Blackash soils—11 percent

Minor components—25 percent (Lithic Haplofibrists, Cinderhill soils, and Kana'a soils)

Component Descriptions

Lava flows

Parent material: Basalt rock

Lithic Ustorthents

Depth class: Shallow

Drainage class: Well drained

Geomorphic position: Tephra deposits and lava fields

Parent material: Tephra over lava flows

Slope: 2 to 15 percent

Ecological site ID: R039XA142AZ

Parent material: Sandstone

Blackash

Depth class: Very deep

Drainage class: Well drained

Geomorphic position: Tephra deposits

Parent material: Tephra deposits

Slope: 2 to 15 percent

Ecological site ID: R039XA142AZ

4—Cumulic Haplustolls consociation

Very deep, level to nearly level, well drained soils that formed from lacustrine deposits

Setting

Ecological site association: Loamy Bottom 17-22" p.z.

Dominant vegetation: Rabbitbrush and blue grama

Landscape: Colorado Plateau

Landform setting: Playa

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Elevation: 6,927 to 6,940 feet (2,111 to 2,115 meters)

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Slope range: 0 to 2 percent

Composition

Extent of the map unit in the survey area: 0.7 percent

Extent of the components in the map unit:

Cumulic Haplustolls—100 percent

Component Description

Cumulic Haplustolls

Depth class: Very deep

Drainage class: Well drained

Geomorphic position: Playa

Parent material: Lacustrine deposits

Slope: 0 to 2 percent

Ecological site ID: R039XA130AZ

Detailed Soil Map Units

The map units delineated on the detailed soil map in this survey represent the soils or miscellaneous areas in the park. The map unit descriptions in this section, along with the map, can be used to determine the suitability and potential of a unit for specific uses. They also can be used to plan the management needed for those uses.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. The contrasting components are mentioned in the map unit descriptions. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives the principal hazards and limitations to be considered in planning for specific uses.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. The soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil map are phases of soil series. The name of a soil

phase commonly indicates a feature that affects use or management. For example, Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes, is a phase of the Sunsetcrater series. The map unit descriptions include a full pedon description for each major soil component. No typical pedons were drawn from outside the boundary of the national monument.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes. A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the map. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Cinderhill-Blackash complex, 15 to 60 percent slopes, is an example.

This survey includes *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Cinder land is an example.

Table 4 lists each map unit in the park, its major and minor components, and the percentage of each component in the unit. Table 5 gives the acreage, number of hectares, and proportionate extent of each map unit. Table 6 identifies the major map unit components in the survey area, the map unit(s) in which each occurs, the component kind, and correlated ecological sites. Other tables give properties of the soils and the limitations, capabilities, and potentials for many uses. The Glossary defines many of the terms used in describing the soils or miscellaneous areas.

20—Cinderhill-Blackash complex, 15 to 60 percent slopes

Map Unit Setting

Landform(s): Cinder cones (figs. 1 and 2)

Elevation: 6,900 to 7,500 feet (2,103 to 2,286 meters)

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Cinderhill and similar soils: 75 percent

Blackash and similar soils: 25 percent

Description of the Cinderhill Soil

Taxonomic classification: Ashy-skeletal, glassy, nonacid, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Backslopes of cinder cones

Parent material: Tephra derived from volcanic rock

Elevation: 6,900 to 7,500 feet (2,103 to 2,286 meters)

Slope: 15 to 60 percent

Drainage class: Excessively drained

K_{sat} of solum: 5.95 to 99.92 inches per hour (42.00 to 705.00 micrometers per second)

Available water capacity (total inches): 1.8 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Low

Hydrologic group: A



Figure 1.—An area of the Cinderhill soil in Cinderhill-Blackash complex, 15 to 60 percent slopes.



Figure 2.—An area of the Blackash soil in Cinderhill-Blackash complex, 15 to 60 percent slopes.



Figure 3.—The Cinderhill soil has a very gravelly coarse sand surface.

Ecological site name: Cindery-Ashy Upland 17-22" p.z.

Ecological site number: R039XA141AZ

Present vegetation: Sand bluestem, ponderosa pine, and crispleaf buckwheat

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 3)

Canopy plant cover—10 percent

Woody debris—0 percent

Herbaceous litter—18 percent

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 4 and 5)

Location by Universal Transverse Mercator System: Zone 12N, 455144 Northing,
3913487 Easting

- C1—0 to 3 inches (0 to 8 centimeters); black (7.5YR 2.5/1) and brown (7.5YR 4/3) very gravelly coarse sand, dark brown (7.5YR 3/3) and black (7.5YR 2.5/1) moist; 4 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 54 percent cinders; noneffervescent; neutral, pH 7.2; clear smooth boundary.
- C2—3 to 7 inches (8 to 18 centimeters); brown (7.5YR 4/3) very gravelly loamy sand, dark brown (7.5YR 3/3) moist; 6 percent clay; single grain; loose, nonsticky and nonplastic; common very fine roots throughout; 50 percent cinders; noneffervescent; slightly alkaline, pH 7.4; abrupt smooth boundary.
- C3—7 to 15 inches (18 to 38 centimeters); black (7.5YR 2.5/1) and reddish brown (5YR 4/3) very gravelly sand, dark reddish brown (5YR 3/3) and black (7.5YR 2.5/1) moist; 5 percent clay; weak fine granular structure; loose, nonsticky and

nonplastic; many very fine, fine, medium, and coarse roots throughout; few fine irregular pores; 54 percent cinders; noneffervescent; slightly alkaline, pH 7.4; clear smooth boundary.

C4—15 to 60 inches (38 to 152 centimeters); black (7.5YR 2.5/1) and 5 percent reddish brown (5YR 4/3) very gravelly coarse sand, black (7.5YR 2.5/1) and 5 percent dark reddish brown (5YR 3/3) moist; 5 percent clay; single grain; loose, nonsticky and nonplastic; many very fine, fine, and medium roots throughout; 58 percent cinders; noneffervescent; slightly alkaline, pH 7.4.

Range in Characteristics

Rock fragments in the control section: 45 to 65 percent cinders

Clay content of particle-size control section: 1 to 8 percent

Volcanic glass content: 30 to 40 percent

C horizons:

Hue—5YR or 7.5YR

Value—2.5 to 4 dry; 2.5 or 3 moist



Figure 4.—Profile of Cinderhill soil. Scale is in centimeters.



Figure 5.—Box sample of Cinderhill typical profile.

Chroma—1 to 3, dry or moist
Texture—coarse sand, sand, or loamy sand
Clay content—1 to 10 percent
Reaction—neutral or slightly alkaline

Description of the Blackash Soil

Taxonomic classification: Ashy, glassy, nonacid, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Backslopes of cinder cones

Parent material: Tephra derived from volcanic rock

Elevation: 6,900 to 7,500 feet (2,103 to 2,286 meters)

Slope: 15 to 60 percent

Drainage class: Excessively drained

K_{sat} of solum: 5.95 to 99.92 inches per hour (42.00 to 705.00 micrometers per second)

Available water capacity (total inches): 1.9 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Low

Hydrologic group: A

Ecological site name: Cindery-Ashy Upland 17-22" p.z.

Ecological site number: R039XA141AZ

Present vegetation: Ponderosa pine, Apache plume, sand bluestem, and blue grama

Land capability classification (nonirrigated areas): 8c

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Surface cover: (fig. 6)

Canopy plant cover—44 percent

Woody debris—0 percent

Herbaceous litter—80 percent

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 7 and 8)

Location by Universal Transverse Mercator System: Zone 12N, 3913397 Northing, 455285 Easting

C1—0 to 2 inches (0 to 5 centimeters); black (7.5YR 2.5/1) and reddish brown (5YR 4/3) gravelly coarse sand, dark reddish brown (5YR 3/3) and black (7.5YR 2.5/1) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; many very fine roots throughout; 27 percent cinders; noneffervescent; slightly alkaline, pH 7.4; clear smooth boundary.

C2—2 to 7 inches (5 to 18 centimeters); brown (7.5YR 4/3) gravelly loamy sand, dark brown (7.5YR 3/2) moist; 4 percent clay; weak fine granular structure; loose, nonsticky and nonplastic; many very fine and fine roots throughout; many fine irregular pores; 31 percent cinders; noneffervescent; neutral, pH 7.2; abrupt smooth boundary.

C3—7 to 16 inches (18 to 41 centimeters); black (7.5YR 2.5/1) and brown (7.5YR 4/3) gravelly loamy coarse sand, dark brown (7.5YR 3/2) and black (7.5YR 2.5/1) moist; 4 percent clay; weak fine granular structure; soft, loose, nonsticky and nonplastic; many very fine, fine, and medium roots; many fine irregular pores; 30 percent cinders; noneffervescent; neutral, pH 7.2; gradual smooth boundary.



Figure 6.—The Blackash soil has a gravelly coarse sand surface.

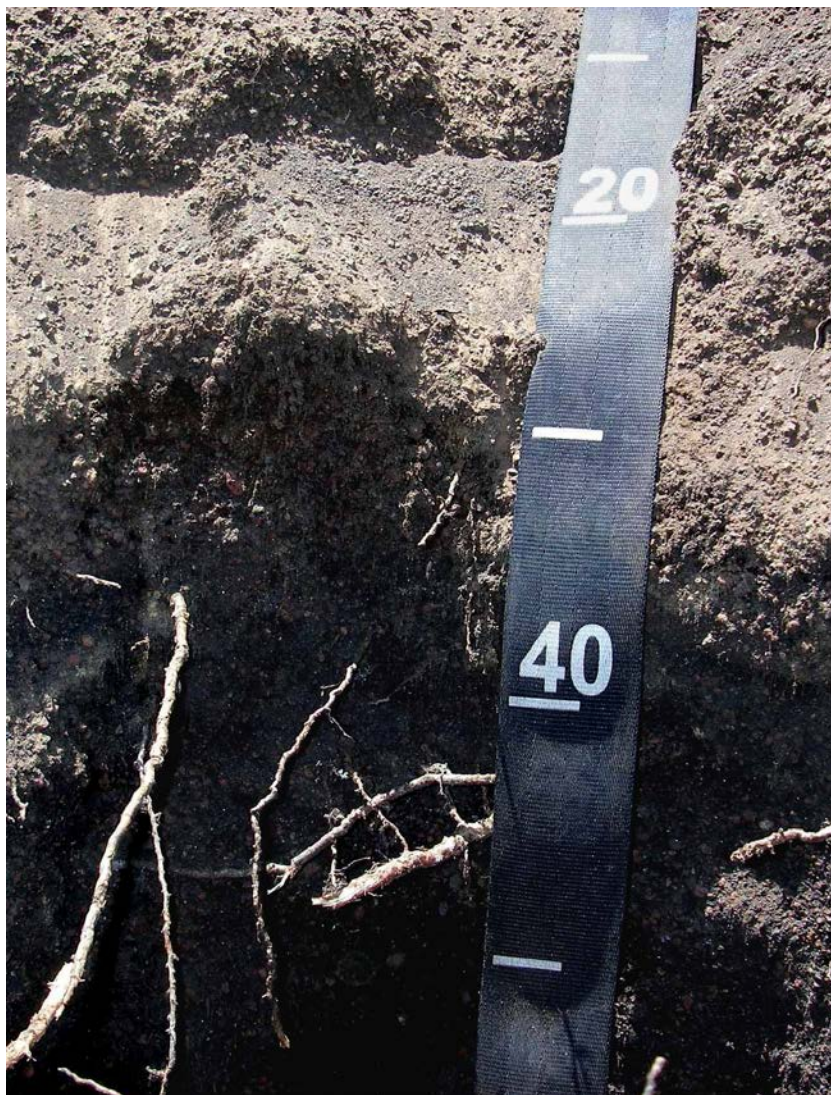


Figure 7.—Profile of Blackash soil. Scale is in centimeters.

C4—16 to 60 inches (41 to 152 centimeters); black (7.5YR 2.5/1) and 5 percent brown (7.5YR 4/3) gravelly coarse sand, black (7.5YR 2.5/1) and 5 percent dark brown (7.5YR 3/2) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; many very fine, fine, and medium roots; 23 percent cinders; noneffervescent; slightly alkaline, pH 7.6.

Range in Characteristics

Rock fragments in the control section: 20 to 35 percent cinders

Clay content of particle-size control section: 1 to 10 percent

Volcanic glass content: 30 to 40 percent

C horizons:

Hue—5YR or 7.5YR

Value—2.5 to 4 dry; 2.5 or 3 moist

Chroma—1 to 3, dry or moist

Texture—coarse sand, loamy coarse sand, or loamy sand

Reaction—neutral or slightly alkaline

21—Cinderhill-Kana`a complex, 3 to 15 percent slopes

Map Unit Setting

Landform(s): Lava fields (figs. 9 and 10)

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Cinderhill and similar soils: 55 percent

Kana`a and similar soils: 30 percent

Minor components: 15 percent (Blackash soils)

Description of the Cinderhill Soil

Taxonomic classification: Ashy-skeletal, glassy, nonacid, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Backslopes of lava fields

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 3 to 15 percent

Drainage class: Excessively drained



Figure 8.—Box sample of Blackash typical profile.



Figure 9.—An area of the Cinderhill soil in Cinderhill-Kana`a complex, 3 to 15 percent slopes.



Figure 10.—An area of the Kana`a soil in Cinderhill-Kana`a complex, 3 to 15 percent slopes.



Figure 11.—The Cinderhill soil has a coarse sand surface.

K_{sat} of solum: 5.95 to 99.92 inches per hour (42.00 to 705.00 micrometers per second)

Available water capacity (total inches): 1.8 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Low

Hydrologic group: A

Ecological site name: Cindery-Ashy Upland 17-22" p.z.

Ecological site number: R039XA141AZ

Present vegetation: Apache plume, ponderosa pine, blue grama, sand bluestem, and wax currant

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 11)

Canopy plant cover—26 percent

Woody debris—0 percent

Herbaceous litter—96 percent

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 12 and 13)

Location by Universal Transverse Mercator System: Zone 12N, 3914703 Northing, 455077 Easting

C1—0 to 2 inches (0 to 5 centimeters); black (10YR 2/1) and brown (7.5YR 4/3) very gravelly loamy sand, dark brown (7.5YR 3/4) and black (10YR 2/1) moist; 6 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots



Figure 12.—Profile of Cinderhill soil. Scale is in centimeters.

throughout; 50 percent cinders; noneffervescent; neutral, pH 7.2; abrupt smooth boundary.

- C2—2 to 6 inches (5 to 15 centimeters); brown (7.5YR 4/3) gravelly loamy sand, dark brown (7.5YR 3/4) moist; 7 percent clay; weak fine granular structure; soft, loose, nonsticky and nonplastic; many very fine, fine, medium, and coarse roots throughout; common fine irregular pores; 27 percent cinders; noneffervescent; slightly alkaline, pH 7.4; abrupt wavy boundary.
- C3—6 to 12 inches (15 to 30 centimeters); black (10YR 2/1) and brown (7.5YR 4/3) very gravelly coarse sand, dark brown (7.5YR 3/4) and black (10YR 2/1) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; many very fine, fine, and medium roots throughout; 46 percent cinders; noneffervescent; neutral, pH 7.2; gradual smooth boundary.
- C4—12 to 60 inches (30 to 152 centimeters); black (10YR 2/1) very gravelly coarse sand, black (10YR 2/1) moist; 2 percent clay; single grain; loose, nonsticky and nonplastic; common very fine and medium and many fine roots throughout; 38 percent cinders; noneffervescent; slightly alkaline, pH 7.4.

Range in Characteristics

Rock fragments in the control section: 35 to 55 percent cinders

Clay content of particle-size control section: 1 to 6 percent

Volcanic glass content: 30 to 40 percent

C horizons:

Hue—2.5YR, 5YR, 7.5YR, or 10YR

Value—2 to 4 dry; 2 or 3 moist

Chroma—1 to 4, dry or moist

Texture—coarse sand or loamy sand

Clay content—1 to 10 percent

Rock fragment content—20 to 55 percent cinders

Reaction—neutral or slightly alkaline

Description of the Kana`a Soil

Taxonomic classification: Cindery, glassy, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Shoulder slopes of lava fields

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 3 to 15 percent

Drainage class: Excessively drained

K_{sat} of solum: 19.98 to 99.92 inches per hour (141.00 to 705.00 micrometers per second)

Available water capacity (total inches): 1.8 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None



Figure 13.—Box sample of Cinderhill typical profile.



Figure 14.—The Kana'a soil has an extremely gravelly coarse sand surface.

Ponding hazard: None

Runoff class: Negligible

Hydrologic group: A

Ecological site name: Cindery-Ashy Upland 17-22" p.z.

Ecological site number: R039XA141AZ

Present vegetation: Apache plume, ponderosa pine, and rabbitbrush

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 14)

Canopy plant cover—0 percent

Woody debris—0 percent

Herbaceous litter—8 percent

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 15 and 16)

Location by Universal Transverse Mercator System: Zone 12N, 3915025 Northing, 454864 Easting

C1—0 to 3 inches (0 to 8 centimeters); black (10YR 2/1) and brown (7.5YR 4/3) extremely gravelly coarse sand, dark brown (7.5YR 3/4) and black (10YR 2/1) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 73 percent cinders; noneffervescent; slightly alkaline, pH 7.4; clear smooth boundary.

C2—3 to 8 inches (8 to 20 centimeters); black (10YR 2/1) and brown (7.5YR 4/3) very gravelly coarse sand, dark brown (7.5YR 3/3) and black (10YR 2/1) moist; 6 percent clay; single grain; loose, nonsticky and nonplastic; few very fine and common fine roots throughout; 42 percent cinders; noneffervescent; slightly alkaline, pH 7.4; abrupt smooth boundary.

- C3—8 to 11 inches (20 to 28 centimeters); black (10YR 2/1) and very dark brown (7.5YR 2.5/2) extremely gravelly coarse sand, dark brown (7.5YR 3/2) and black (10YR 2/1) moist; 5 percent clay; single grain; loose, nonsticky and nonplastic; many very fine, fine, and medium roots throughout; few very fine irregular pores; 62 percent cinders; noneffervescent; slightly alkaline, pH 7.6; abrupt wavy boundary.
- C4—11 to 60 inches (28 to 152 centimeters); black (10YR 2/1) extremely gravelly coarse sand, black (10YR 2/1) moist; 2 percent clay; single grain; loose, nonsticky and nonplastic; many very fine, common fine, and few medium roots throughout; 88 percent cinders; noneffervescent; slightly alkaline, pH 7.4.

Range in Characteristics

Rock fragments in the control section: 60 to 90 percent cinders

Clay content of particle-size control section: 1 to 8 percent

Volcanic glass content: 30 to 40 percent



Figure 15.—Profile of Kana'a soil. Scale is in centimeters.



Figure 16.—Box sample of Kana'a typical profile.

C horizons:

Hue—5YR, 7.5YR, or 10YR
Value—2 to 4 dry; 2 or 3 moist
Chroma—1 to 4, dry or moist
Texture—coarse sand
Clay content—1 to 8 percent
Rock fragment content—35 to 90 percent cinders
Reaction—neutral or slightly alkaline

22—Cinderhill-Lava flows complex, 2 to 15 percent slopes

Map Unit Setting

Landform(s): Lava fields and lava flows (figs. 17 and 18)
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)
Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)
Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)
Frost-free period: 100 to 120 days
Major land resource area: 39—Arizona and New Mexico Mountains
Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Cinderhill and similar soils: 65 percent



Figure 17.—An area of the Cinderhill soil in Cinderhill-Lava flows complex, 2 to 15 percent slopes.



Figure 18.—An area of the Lava flows in Cinderhill-Lava flows complex, 2 to 15 percent slopes.



Figure 19.—The Cinderhill soil has a very gravelly coarse sand surface.

Lava flows: 15 percent

Minor components: 20 percent (Kana`a soils)

Description of the Cinderhill Soil

Taxonomic classification: Ashy-skeletal, glassy, nonacid, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Shoulder slopes of lava fields

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 2 to 15 percent

Drainage class: Excessively drained

K_{sat} of solum: 19.98 to 99.92 inches per hour (141.00 to 705.00 micrometers per second)

Available water capacity (total inches): 1.8 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Very low

Hydrologic group: A

Ecological site name: Cinder Cones 17-22" p.z.

Ecological site number: R039XA143AZ

Present vegetation: Buckwheat, ponderosa pine, and rabbitbrush

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 19)

Canopy plant cover—0 percent

Woody debris—0 percent

Herbaceous litter—0 percent

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 20 and 21)

Location by Universal Transverse Mercator System: Zone 12N, 3914320 Northing, 453378 Easting

C1—0 to 2 inches (0 to 5 centimeters); reddish brown (5YR 4/4) very gravelly coarse sand, dark reddish brown (5YR 3/4) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; common very fine tubular pores; 45 percent cinders; noneffervescent; neutral, pH 7.2; clear smooth boundary.

C2—2 to 7 inches (5 to 18 centimeters); dark reddish brown (5YR 3/4) extremely gravelly sand, dark reddish brown (5YR 3/4) moist; 5 percent clay; single grain; loose, nonsticky and nonplastic; common very fine roots throughout; common very fine tubular pores; 65 percent cinders; noneffervescent; slightly alkaline, pH 7.4; gradual smooth boundary.



Figure 20.—Profile of Cinderhill soil. Scale is in centimeters.



Figure 21.—Box sample of Cinderhill typical profile.

C3—7 to 60 inches (18 to 152 centimeters); dark reddish brown (5YR 3/4) very gravelly coarse sand, dark reddish brown (5YR 3/4) moist; 5 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; common very fine tubular pores; 53 percent cinders; very slightly effervescent, 1 percent calcium carbonate equivalent; neutral, pH 7.2.

Range in Characteristics

Rock fragments in the control section: 35 to 75 percent cinders

Clay content of particle-size control section: 1 to 6 percent

Volcanic glass content: 30 to 40 percent

C horizons:

Hue—5YR

Value—2.5 to 4 dry; 3 or 4 moist

Chroma—1 to 4, dry or moist

Texture—coarse sand or sand

Calcium carbonate equivalent—0 to 2 percent

Reaction—neutral or slightly alkaline

Description of Lava Flows

Lava flows typically have sharp, jagged surfaces, crevices, and angular blocks that are characteristic of basalt lava. Although a little earthy material may have accumulated in a few rocks and sheltered pockets, the flows are virtually devoid of vegetation, with the exception of lichens.

23—Cumulic Haplustolls extremely gravelly sandy loam, 0 to 2 percent slopes

Map Unit Setting

Landform(s): Flood-plain steps (fig. 22)

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Cumulic Haplustolls and similar soils: 100 percent

Description of the Cumulic Haplustolls

Taxonomic classification: Coarse-loamy, mixed, superactive, frigid Cumulic Haplustolls

Taxon kind: Taxon above family

Geomorphic position: Toeslopes of flood plain-steps

Parent material: Alluvium derived from volcanic and sedimentary rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 0 to 2 percent

Drainage class: Well drained

K_{sat} of solum: 0.57 inch to 19.98 inches per hour (4.00 to 141.00 micrometers per second)

Available water capacity (total inches): 3.8 (low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: Very rare

Ponding hazard: None

Runoff class: Low

Hydrologic group: B



Figure 22.—An area of Cumulic Haplustolls, extremely gravelly sandy loam, 0 to 2 percent slopes.



Figure 23.—The Cumulic Haplustolls have an extremely gravelly sandy loam surface.

Ecological site name: Loamy Bottom 17-22" p.z.

Ecological site number: R039XA130AZ

Present vegetation: Rabbitbrush, blue grama, aster, geranium, and prairie flax

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 23)

Canopy plant cover—26 percent

Woody debris—0 percent

Herbaceous litter—50 percent

Bare soil—0 percent

Rock fragments—40 percent gravel

Typical Pedon (figs. 24 and 25)

Location by Universal Transverse Mercator System: Zone 12N, 3914268 Northing, 450097 Easting

A1—0 to 2 inches (0 to 5 centimeters); brown (7.5YR 5/2) extremely gravelly sandy loam, very dark gray (7.5YR 3/1) moist; 12 percent clay; weak fine granular structure; loose, nonsticky and nonplastic; many very fine and fine roots throughout; many very fine tubular pores; 61 percent gravel; noneffervescent; neutral, pH 7.2; clear smooth boundary.

A2—2 to 8 inches (5 to 20 centimeters); brown (7.5YR 5/2) extremely gravelly sandy loam, dark brown (7.5YR 3/2) moist; 12 percent clay; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots throughout; many very fine tubular pores; 61 percent gravel; noneffervescent; slightly alkaline, pH 7.4; clear smooth boundary.

C1—8 to 15 inches (20 to 38 centimeters); brown (10YR 5/3) sandy loam, dark brown (10YR 3/3) moist; 14 percent clay; massive; moderately hard, friable, slightly sticky and slightly plastic; common very fine and fine roots throughout; few very fine

- and common fine tubular pores; 8 percent gravel; noneffervescent; moderately alkaline, pH 8.0; clear smooth boundary.
- C2—15 to 27 inches (38 to 69 centimeters); brown (7.5YR 5/4) gravelly loam, dark brown (7.5YR 3/3) moist; 16 percent clay; massive; slightly hard, very friable, slightly sticky and slightly plastic; few very fine and fine roots throughout; common very fine and few fine tubular pores; 20 percent gravel; noneffervescent; slightly alkaline, pH 7.8; gradual smooth boundary.
- C3—27 to 55 inches (69 to 140 centimeters); light yellowish brown (10YR 6/4) gravelly loamy sand, brown (10YR 4/3) moist; 10 percent clay; massive; loose, nonsticky and nonplastic; few very fine roots throughout; 23 percent gravel; noneffervescent; slightly alkaline, pH 7.4; clear smooth boundary.
- C4—55 to 60 inches (140 to 152 centimeters); gray (10YR 5/1) and light yellowish brown (10YR 6/4) very gravelly loamy sand, very dark gray (10YR 3/1) and brown (10YR 4/3) moist; 10 percent clay; massive; loose, nonsticky and nonplastic; few very fine roots throughout; 42 percent gravel; noneffervescent; slightly alkaline, pH 7.4.

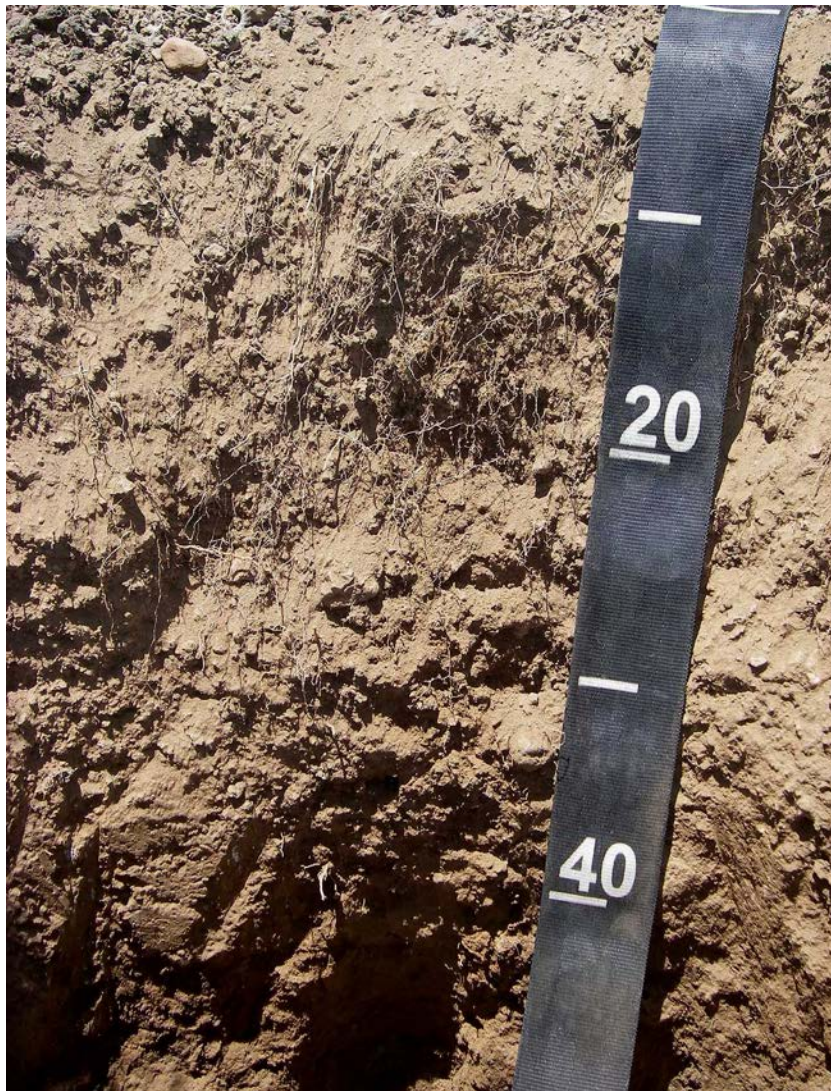


Figure 24.—Profile of Cumulic Haplustolls. Scale is in centimeters.

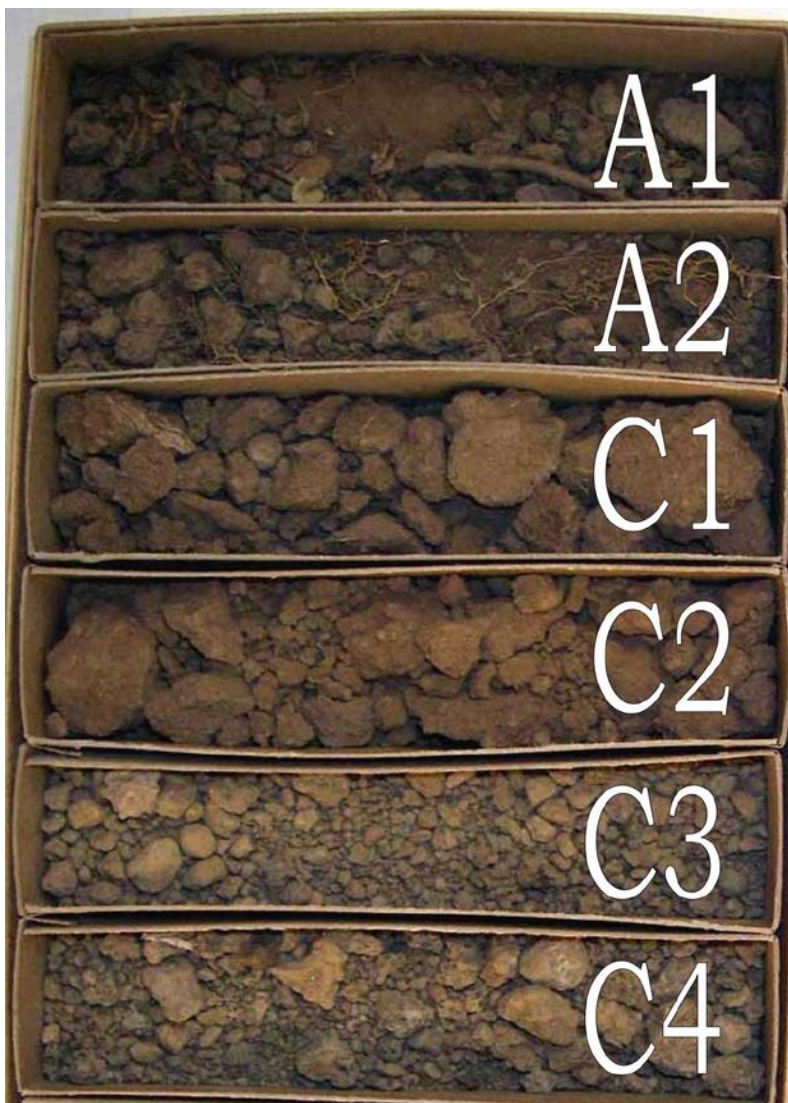


Figure 25.—Box sample of Cumulic Haplustolls typical profile.

Range in Characteristics

Note: Cumulic Haplustolls have soil properties that vary beyond family class limits.

Rock fragments in the control section: 5 to 30 percent gravel

Clay content of particle-size control section: 6 to 18 percent

Mollic epipedon: Zone at depths between 0 and 27 inches (0 and 69 centimeters)

A horizons:

Hue—7.5YR or 10YR

Value—2 to 5 dry; 2 or 3 moist

Chroma—1 to 3, dry or moist

Texture—sandy loam

Clay content—10 to 18 percent

Rock fragment content—40 to 70 percent gravel

Reaction—neutral or slightly alkaline

Upper C horizons:

Hue—7.5YR or 10YR
Value—5 or 6 dry; 3 or 4 moist
Chroma—3 or 4, dry or moist
Texture—loam or sandy loam
Clay content—12 to 18 percent
Rock fragment content—5 to 30 percent gravel
Reaction—neutral to moderately alkaline

Lower C horizons:

Hue—7.5YR or 10YR
Value—5 or 6 dry; 3 or 4 moist
Chroma—1 to 4, dry or moist
Texture—loamy sand
Clay content—6 to 12 percent
Rock fragment content—15 to 50 percent gravel
Reaction—neutral or slightly alkaline

24—Kana`a extremely gravelly sand, 1 to 3 percent slopes

Map Unit Setting

Landform(s): Lava fields (fig. 26)

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)



Figure 26.—An area of Kana`a extremely gravelly sand, 1 to 3 percent slopes.

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Kana`a and similar soils: 90 percent

Minor components: 10 percent (Cinderhill soils)

Description of the Kana`a Soil

Taxonomic classification: Cindery, glassy, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Footslopes of lava fields

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 1 to 3 percent

Drainage class: Excessively drained

K_{sat} of solum: 19.98 to 99.92 inches per hour (141.00 to 705.00 micrometers per second)

Available water capacity (total inches): 1.8 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Negligible

Hydrologic group: A

Ecological site name: Cindery-Ashy Upland 17-22" p.z.

Ecological site number: R039XA141AZ

Present vegetation: Apache plume, ponderosa pine, and blue grama

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 27)

Canopy plant cover—18 percent

Woody debris—0 percent

Herbaceous litter—68 percent

Bare soil—0 percent

Rock fragments—98 percent cinders

Typical Pedon (figs. 28 and 29)

Location by Universal Transverse Mercator System: Zone 12N, 3915239 Northing, 455675 Easting

C1—0 to 2 inches (0 to 5 centimeters); dark grayish brown (10YR 4/2) extremely gravelly sand, very dark grayish brown (10YR 3/2) and very dark brown (10YR 2/2) moist; 4 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; few fine dendritic tubular pores; 73 percent cinders; noneffervescent; neutral, pH 7.2; abrupt smooth boundary.

C2—2 to 4 inches (5 to 10 centimeters); brown (10YR 4/3) extremely gravelly sand, dark brown (7.5YR 3/2) and black (10YR 2/1) moist; 4 percent clay; weak very fine granular structure; soft, loose, nonsticky and nonplastic; many very fine and fine and common medium and coarse roots throughout; few fine irregular pores; 65 percent cinders; noneffervescent; neutral, pH 6.8; abrupt smooth boundary.



Figure 27.—The Kana'a soil has an extremely gravelly sand surface.

C3—4 to 8 inches (10 to 20 centimeters); black (10YR 2/1) extremely gravelly coarse sand, black (10YR 2/1) moist; 2 percent clay; single grain; loose, nonsticky and nonplastic; many very fine and fine and common medium and coarse roots throughout; 88 percent cinders; noneffervescent; slightly alkaline, pH 7.6; gradual smooth boundary.

C4—8 to 19 inches (20 to 48 centimeters); black (10YR 2/1) extremely gravelly coarse sand, black (10YR 2/1) moist; 2 percent clay; single grain; loose, nonsticky and nonplastic; many very fine and fine and few medium roots throughout; 65 percent cinders; noneffervescent; slightly alkaline, pH 7.8; gradual smooth boundary.

C5—19 to 60 inches (48 to 152 centimeters); black (10YR 2/1) extremely gravelly coarse sand, black (10YR 2/1) moist; 1 percent clay; single grain; loose, nonsticky and nonplastic; few very fine, fine, and coarse and common medium roots throughout; 77 percent cinders; noneffervescent; slightly alkaline, pH 7.6.

Range in Characteristics

Rock fragments in the control section: 60 to 88 percent cinders

Clay content of particle-size control section: 1 to 4 percent

Volcanic glass content: 30 to 40 percent

C horizons:

Hue—7.5YR or 10YR

Value—2 to 4 dry; 2 or 3 moist

Chroma—1 to 3, dry or moist

Texture—coarse sand or sand

Clay content—1 to 6 percent

Reaction—neutral or slightly alkaline



Figure 28.—Profile of Kana`a soil. Scale is in centimeters.

25—Kana`a-Cinder land complex, 1 to 15 percent slopes

Map Unit Setting

Landform(s): Lava fields (figs. 30 and 31)

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Kana`a and similar soils: 80 percent

Cinder land: 20 percent

Description of the Kana`a Soil

Taxonomic classification: Cindery, glassy, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Summits of lava fields

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 1 to 15 percent

Drainage class: Excessively drained

K_{sat} of solum: 19.98 to 99.92 inches per hour (141.00 to 705.00 micrometers per second)

Available water capacity (total inches): 1.8 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Negligible

Hydrologic group: A



Figure 29.—Box sample of Kana`a typical profile.



Figure 30.—An area of the Kana`a soil in Kana`a-Cinder land complex, 1 to 15 percent slopes.



Figure 31.—An area of the Cinder land in Kana`a-Cinder land complex, 1 to 15 percent slopes.



Figure 32.—The Kana`a soil has an extremely gravelly coarse sand surface.

Ecological site name: Cinder Cones 17-22" p.z.

Ecological site number: R039XA143AZ

Present vegetation: None

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 32)

Canopy plant cover—0 percent

Woody debris—0 percent

Herbaceous litter—0 percent

Bare soil—0 percent

Rock fragments—92 percent cinders

Typical Pedon (figs. 33 and 34)

Location by Universal Transverse Mercator System: Zone 12N, 3915366 Northing,
454430 Easting

C1—0 to 2 inches (0 to 5 centimeters); brown (10YR 4/3) and dark gray (10YR 4/1) extremely gravelly coarse sand, very dark grayish brown (10YR 3/2) and black (10YR 2/1) moist; 4 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 85 percent cinders; noneffervescent; neutral, pH 6.8; clear smooth boundary.

C2—2 to 4 inches (5 to 10 centimeters); brown (10YR 4/3) and black (10YR 2/1) very gravelly coarse sand, very dark grayish brown (10YR 3/2) and black (10YR 2/1) moist; 4 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 46 percent cinders; noneffervescent; slightly alkaline, pH 7.6; abrupt smooth boundary.



Figure 33.—Profile of Kana'a soil. Scale is in centimeters on the right and in inches on the left.

C3—4 to 60 inches (10 to 152 centimeters); black (10YR 2/1) extremely gravelly coarse sand, black (10YR 2/1) moist; 4 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 85 percent cinders; noneffervescent; slightly alkaline, pH 7.6.

Range in Characteristics

Rock fragments in the control section: 65 to 85 percent cinders

Clay content of particle-size control section: 1 to 6 percent

Volcanic glass content: 30 to 40 percent

C horizons:

Hue—5YR, 7.5YR, or 10YR

Value—2 to 4 dry; 2 or 3 moist

Chroma—1 to 3, dry or moist

Texture—coarse sand

Reaction—neutral or slightly alkaline

Description of Cinder Land

Cinder land areas are exposures of loose cinders and other scoriaceous magmatic ejecta, which are barren and have no roots in the soil profile. The surface is unstable, and trafficability is poor.

26—Kana`a-Cinder land complex, 15 to 60 percent slopes

Map Unit Setting

Landform(s): Cinder cones (figs. 35 and 36)

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Kana`a and similar soils: 65 percent

Cinder land: 35 percent

Description of the Kana`a Soil

Taxonomic classification: Cindery, glassy, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Backslopes of cinder cones

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 15 to 60 percent



Figure 34.—Box sample of Kana`a typical profile.



Figure 35.—An area of the Kana`a soil in Kana`a-Cinder land complex, 15 to 60 percent slopes.



Figure 36.—An area of the Cinder land in Kana`a-Cinder land complex, 15 to 60 percent slopes.



Figure 37.—The Kana`a soil has an extremely coarse sand surface.

Drainage class: Excessively drained

K_{sat} of solum: 5.95 to 99.92 inches per hour (42.00 to 705.00 micrometers per second)

Available water capacity (total inches): 0.7 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Low

Hydrologic group: A

Ecological site name: Cinder Cones 17-22" p.z.

Ecological site number: R039XA143AZ

Present vegetation: None

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 37)

Canopy plant cover—0 percent

Woody debris—0 percent

Herbaceous litter—0 percent

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 38 and 39)

Location by Universal Transverse Mercator System: Zone 12N, 3915679 Northing, 454122 Easting

C1—0 to 3 inches (0 to 8 centimeters); dark gray (10YR 4/1) extremely gravelly coarse sand, black (10YR 2/1) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 76 percent cinders; noneffervescent; neutral, pH 7.2; clear smooth boundary.



Figure 38.—Profile of Kana'a soil. Scale is in centimeters.

C2—3 to 6 inches (8 to 15 centimeters); black (10YR 2/1) extremely gravelly loamy sand, black (10YR 2/1) moist; 6 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 77 percent cinders; noneffervescent; neutral, pH 7.2; abrupt smooth boundary.

C3—6 to 60 inches (15 to 152 centimeters); black (10YR 2/1) gravel, black (10YR 2/1) moist; 4 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 96 percent cinders; noneffervescent; neutral, pH 7.2.

Range in Characteristics

Rock fragments in the control section: 65 to 96 percent cinders

Clay content of particle-size control section: 1 to 10 percent

Volcanic glass content: 30 to 40 percent

C1 or C2 horizon:

Hue—5YR, 7.5YR, or 10YR

Value—2 to 4 dry; 2 or 3 moist

Chroma—1 or 2, dry or moist

Texture—coarse sand or loamy sand
Rock fragment content—65 to 85 percent cinders
Reaction—neutral or slightly alkaline

C3 horizon:

Clay content—1 to 5 percent
Rock fragment content—90 to 96 percent cinders
Reaction—neutral or slightly alkaline

Description of Cinder Land

Cinder land areas are exposures of loose cinders and other scoriaceous magmatic ejecta, which are barren and have no roots in the soil profile. The surface is unstable, and trafficability is poor.

27—Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes

Map Unit Setting

Landform(s): À`a lava flows (figs. 40 and 41)
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)
Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)
Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)
Frost-free period: 100 to 120 days
Major land resource area: 39—Arizona and New Mexico Mountains
Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Lava flows: 80 percent
Lithic Haplofibrists and similar soils: 20 percent



Figure 39.—Box sample of Kana`a typical profile.



Figure 40.—An area of the Lava flows in Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes.



Figure 41.—An area of the Lithic Haplofibrists in Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes. A shrub is growing inside a lava flow crack.

Description of Lava Flows

Lava flows typically have sharp, jagged surfaces, crevices, and angular blocks that are characteristic of basalt lava. Although a little earthy material may have accumulated in a few rocks and sheltered pockets, the flows are virtually devoid of vegetation, with the exception of lichens.

Description of the Lithic Haplofibrists

Taxonomic classification: Euic, frigid Lithic Haplofibrists

Taxon kind: Taxon above family

Geomorphic position: Footslopes of `a`a lava flows

Parent material: Organic material over tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 2 to 15 percent

Depth to restrictive feature: 2 to 4 inches to lithic bedrock

Drainage class: Well drained

K_{sat} of solum: 0.57 inch to 1.98 inches per hour (4.00 to 14.00 micrometers per second)

K_{sat} of restrictive layer: 0.00 to 0.06 inch per hour (0.00 to 0.42 micrometer per second)

Available water capacity (total inches): 0.1 (very low)

Shrink-swell potential: About 4.5 LEP (moderate)

Flooding hazard: None

Ponding hazard: None

Runoff class: Low

Hydrologic group: D

Ecological site name: Cinders-Lava Flow Upland 17-22" p.z.

Ecological site number: R039XA142AZ

Present vegetation: Apache plume and wax currant

Land capability classification (nonirrigated areas): 8c

Surface cover:

Canopy plant cover—10 percent

Woody debris—0 percent

Herbaceous litter—0 percent

Bare soil—0 percent

Rock fragments—100 percent stones

Typical Pedon (figs. 42 and 43)

Location by Universal Transverse Mercator System: Zone 12N, 3913118 Northing, 452595 Easting

Oi—0 to 3 inches (0 to 8 centimeters); very dark brown (10YR 2/2) slightly decomposed plant material, black (10YR 2/1) moist; massive; nonsticky and nonplastic; many very fine and fine roots throughout; many fine irregular pores; noneffervescent; neutral, pH 7.2; abrupt wavy boundary.

A—3 to 4 inches (8 to 10 centimeters); very dark grayish brown (10YR 3/2) very gravelly loam, very dark brown (10YR 2/2) moist; 20 percent clay; weak very fine granular structure; soft, very friable, nonsticky and slightly plastic; many very fine, fine, and medium roots throughout; many fine tubular pores; 30 percent cinders, 5 percent stones, and 5 percent cobbles; noneffervescent; slightly alkaline, pH 7.4; abrupt irregular boundary.

R—4 inches (10 centimeters); fractured, unweathered volcanic bedrock.

Range in Characteristics

Note: Lithic Haplofibrists have soil properties that vary beyond family class limits.



Figure 42.—Sample of Lithic Haplofibrists.



Figure 43.—Box sample of Lithic Haplofibrists typical profile.

Rock fragments in the control section: 35 to 55 percent cinders, cobbles, and stones
Clay content of particle-size control section: 18 to 25 percent

A horizon:

Hue—10YR

Value—2 to 4 dry; 2 or 3 moist

Chroma—1 or 2, dry or moist

Texture—loam

Clay content—18 to 25 percent

Rock fragment content—35 to 55 percent cinders, cobbles, and stones

Reaction—neutral or slightly alkaline



Figure 44.—An area of the Lithic Ustorthents in Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes.

28—Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes

Map Unit Setting

Landform(s): Lava fields and lava flows (figs. 44, 45, and 46)

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Lithic Ustorthents and similar soils: 40 percent

Blackash and similar soils: 35 percent

Lava flows: 25 percent

Description of the Lithic Ustorthents

Taxonomic classification: Ashy-skeletal, glassy, nonacid, frigid Lithic Ustorthents

Taxon kind: Taxon above family

Geomorphic position: Shoulder slopes of lava fields

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)



Figure 45.—An area of the Blackash soil in Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes.



Figure 46.—An area of the Lava flows in Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes.



Figure 47.—The Lithic Ustorthents have a very gravelly loamy sand surface.

Slope: 2 to 15 percent

Depth to restrictive feature: 2 to 14 inches to lithic bedrock

Drainage class: Excessively drained

K_{sat} of solum: 5.95 to 99.92 inches per hour (42.00 to 705.00 micrometers per second)

K_{sat} of restrictive layer: 0.00 to 0.06 inch per hour (0.00 to 0.42 micrometer per second)

Available water capacity (total inches): 0.5 (very low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

Runoff class: Negligible

Hydrologic group: D

Ecological site name: Cinders-Lava Flow Upland 17-22" p.z.

Ecological site number: R039XA142AZ

Present vegetation: Ponderosa pine, Apache plume, and wax currant

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 47)

Canopy plant cover—28 percent

Woody debris—0 percent

Herbaceous litter—58 percent

Bare soil—0 percent

Rock fragments—86 percent cinders and 10 percent boulders

Typical Pedon (figs. 48 and 49)

Location by Universal Transverse Mercator System: Zone 12N, 3913757 Northing, 452747 Easting

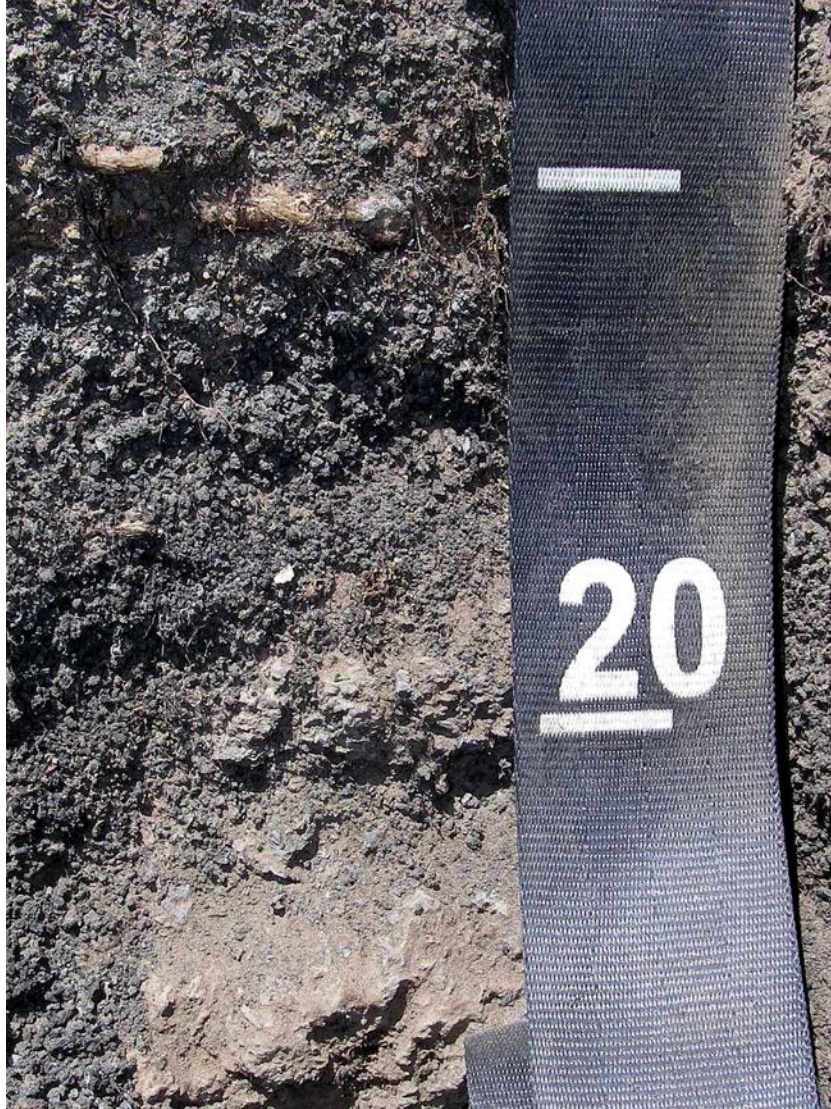


Figure 48.—Profile of Lithic Ustorthents. Scale is in centimeters.

- C1—0 to 2 inches (0 to 5 centimeters); very dark gray (7.5YR 3/1) very gravelly loamy sand, black (7.5YR 2.5/1) moist; 7 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 35 percent cinders; noneffervescent; slightly alkaline, pH 7.6; clear smooth boundary.
- C2—2 to 4.5 inches (5 to 11 centimeters); very dark gray (7.5YR 3/1) gravelly sand, black (7.5YR 2.5/1) moist; 6 percent clay; weak fine granular structure; loose, nonsticky and nonplastic; many very fine and fine roots throughout; few fine irregular pores; 20 percent cinders; noneffervescent; slightly alkaline, pH 7.8; clear smooth boundary.
- C3—4.5 to 14 inches (11 to 36 centimeters); black (7.5YR 2.5/1) very gravelly coarse sand, black (7.5YR 2.5/1) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; many very fine and fine roots throughout; 50 percent cinders; noneffervescent; slightly alkaline, pH 7.8; abrupt wavy boundary.
- R—14 inches (36 centimeters); fractured, unweathered volcanic bedrock.

Range in Characteristics

Note: Lithic Ustorthents have soil properties that vary beyond family class limits.

Rock fragments in the control section: 15 to 55 percent cinders

Clay content of particle-size control section: 1 to 10 percent

C horizons:

Hue—5YR, 7.5YR, or 10YR

Value—2 to 4, dry or moist

Chroma—1 or 2, dry or moist

Texture—coarse sand, sand, or loamy sand

Clay content—1 to 10 percent

Rock fragment content—15 to 55 percent cinders

Reaction—neutral or slightly alkaline

Description of the Blackash Soil

Taxonomic classification: Ashy, glassy, nonacid, frigid Vitrandic Ustorthents

Taxon kind: Series

Geomorphic position: Shoulder slopes of lava fields

Parent material: Tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Slope: 2 to 15 percent

Drainage class: Excessively drained

K_{sat} of solum: 19.98 to 99.92 inches per hour (141.00 to 705.00 micrometers per second)

Available water capacity (total inches): 2.8 (low)

Shrink-swell potential: About 1.5 LEP (low)

Flooding hazard: None

Ponding hazard: None

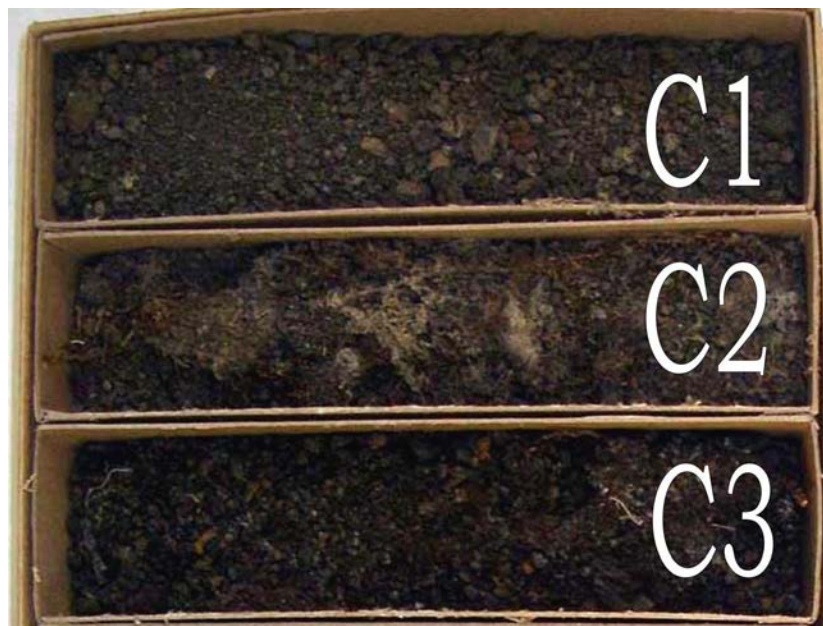


Figure 49.—Box sample of Lithic Ustorthents typical profile.



Figure 50.—The Blackash soil has a gravelly sand surface.

Runoff class: Negligible

Hydrologic group: A

Ecological site name: Cinders-Lava Flow Upland 17-22" p.z.

Ecological site number: R039XA142AZ

Present vegetation: Ponderosa pine, Apache plume, and wax currant

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 50)

Canopy plant cover—24 percent

Woody debris—0 percent

Herbaceous litter—50 percent

Bare soil—0 percent

Rock fragments—96 percent cinders and 4 percent boulders

Typical Pedon (figs. 51 and 52)

Location by Universal Transverse Mercator System: Zone 12N, 33913778 Northing, 452761 Easting

C1—0 to 3 inches (0 to 8 centimeters); very dark gray (7.5YR 3/1) gravelly sand, black (7.5YR 2.5/1) moist; 5 percent clay; single grain; loose, nonsticky and nonplastic; common very fine roots throughout; 20 percent cinders; noneffervescent; neutral, pH 7.2; clear smooth boundary.

C2—3 to 9 inches (8 to 23 centimeters); very dark gray (7.5YR 3/1) gravelly coarse sand, black (7.5YR 2.5/1) moist; 3 percent clay; weak fine granular structure and single grain; loose, nonsticky and nonplastic; many very fine and fine roots throughout; 15 percent cinders; noneffervescent; slightly alkaline, pH 7.4; clear smooth boundary.

C3—9 to 16 inches (23 to 41 centimeters); black (7.5YR 2.5/1) extremely gravelly coarse sand, black (7.5YR 2.5/1) moist; 3 percent clay; single grain; loose, nonsticky and nonplastic; many very fine roots throughout; 60 percent cinders; noneffervescent; slightly alkaline, pH 7.4; gradual smooth boundary.

C4—16 to 60 inches (41 to 152 centimeters); black (7.5YR 2.5/1) gravelly sand, black (7.5YR 2.5/1) moist; 5 percent clay; single grain; loose, nonsticky and nonplastic; few very fine roots throughout; 27 percent cinders; noneffervescent; slightly alkaline, pH 7.4.

Range in Characteristics

Rock fragments in the control section: 15 to 35 percent cinders

Clay content of particle-size control section: 1 to 6 percent

Volcanic glass content: 30 to 40 percent

C1 or C2 horizon:

Hue—5YR, 7.5YR, or 10YR



Figure 51.—Profile of Blackash soil. Scale is in centimeters.



Figure 52.—Box sample of Blackash typical profile.

Value—2 to 4 dry; 2.5 or 3 moist
Chroma—1 or 2, dry or moist
Texture—coarse sand or sand
Rock fragment content—15 to 30 percent cinders
Reaction—neutral or slightly alkaline

C3 horizon:

Hue—5YR, 7.5YR, or 10YR
Value—2 to 4 dry; 2 or 3 moist
Chroma—1 or 2, dry or moist
Texture—coarse sand
Rock fragment content—30 to 70 percent cinders
Reaction—neutral or slightly alkaline

C4 horizon:

Hue—5YR, 7.5YR, or 10YR
Value—2 to 4 dry; 2 or 3 moist
Chroma—1 or 2, dry or moist
Texture—sand
Rock fragment content—15 to 30 percent cinders
Reaction—neutral or slightly alkaline

Description of Lava Flows

Lava flows typically have sharp, jagged surfaces, crevices, and angular blocks that are characteristic of basalt lava. Although a little earthy material may have accumulated in a few rocks and sheltered pockets, the flows are virtually devoid of vegetation, with the exception of lichens.

29—Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes

Map Unit Setting

Landform(s): Lava fields (fig. 53)

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)

Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)

Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)

Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)

Frost-free period: 100 to 120 days

Major land resource area: 39—Arizona and New Mexico Mountains

Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Sunsetcrater and similar soils: 95 percent

Minor components: 5 percent (ashy-skeletal Vitrandic Haplustepts)

Description of the Sunsetcrater Soil

Taxonomic classification: Cindery, glassy, frigid Vitrandic Haplustepts

Taxon kind: Taxadjunct

Geomorphic position: Shoulder slopes of lava fields

Parent material: Tephra derived from volcanic rock over clayey tephra derived from volcanic rock

Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)



Figure 53.—An area of Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes.



Figure 54.—The Sunsetcrater soil has an extremely gravelly loamy sand surface.

Slope: 1 to 15 percent

Drainage class: Well drained

K_{sat} of solum: 0.57 inch to 99.92 inches per hour (4.00 to 705.00 micrometers per second)

Available water capacity (total inches): 3.3 (low)

Shrink-swell potential: About 4.5 LEP (moderate)

Flooding hazard: None

Ponding hazard: None

Runoff class: Low

Hydrologic group: B

Ecological site name: Cindery-Ashy Upland 17-22" p.z.

Ecological site number: R039XA141AZ

Present vegetation: Ponderosa pine and Canada wildrye

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 54)

Canopy plant cover—38 percent

Woody debris—0 percent

Herbaceous litter—82 percent

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 55 and 56)

Location by Universal Transverse Mercator System: Zone 12N, 3915583 Northing, 451778 Easting

C1—0 to 2 inches (0 to 5 centimeters); very dark grayish brown (10YR 3/2) extremely gravelly loamy sand, very dark brown (10YR 2/2) moist; 6 percent clay; single

- grain; loose, nonsticky and nonplastic; common very fine roots throughout; 80 percent cinders; noneffervescent; neutral, pH 6.6; abrupt smooth boundary.
- C2—2 to 8 inches (5 to 20 centimeters); very dark grayish brown (10YR 3/2) extremely gravelly loamy coarse sand, very dark brown (10YR 2/2) moist; 8 percent clay; weak fine granular structure and single grain; loose, nonsticky and nonplastic; many very fine and fine roots throughout; common very fine tubular pores; 72 percent cinders; noneffervescent; neutral, pH 7.2; clear smooth boundary.
- C3—8 to 18 inches (20 to 46 centimeters); black (10YR 2/1) extremely gravelly coarse sand, black (10YR 2/1) moist; 2 percent clay; single grain; loose, nonsticky and nonplastic; many very fine and common fine roots throughout; 87 percent cinders; noneffervescent; slightly alkaline, pH 7.6; clear smooth boundary.
- 2Bw—18 to 32 inches (46 to 81 centimeters); dark yellowish brown (10YR 4/6) extremely gravelly sandy clay loam, dark yellowish brown (10YR 3/6) moist; 20 percent clay; weak fine subangular blocky structure; soft, very friable, moderately sticky and moderately plastic; common very fine and fine roots throughout;



Figure 55.—Profile of Sunsetcrater soil. Scale is in centimeters.



Figure 56.—Box sample of Sunsetcrater typical profile.

common very fine tubular pores; 73 percent cinders; noneffervescent; slightly alkaline, pH 7.6; gradual smooth boundary.

2C—32 to 60 inches (81 to 152 centimeters); dark yellowish brown (10YR 4/4) very gravelly sandy loam, dark yellowish brown (10YR 3/4) moist; 16 percent clay; single grain; soft, very friable, slightly sticky and slightly plastic; few very fine and fine roots throughout; 50 percent cinders; very slightly effervescent, 1 percent calcium carbonate equivalent; moderately alkaline, pH 8.0.

Range in Characteristics

Note: Sunsetcrater soils in this survey area are considered a taxadjunct to the series because they have a cindery particle-size classification and glassy mineralogy. The Sunsetcrater series is classified as ashy-skeletal, glassy, frigid Vitrandic Haplustepts.

Rock fragments in the control section: 35 to 87 percent cinders

Clay content of particle-size control section: 1 to 25 percent

Volcanic glass content: 30 to 40 percent

Cambic horizon: Zone between depths of 18 and 32 inches (46 and 81 centimeters)

C horizons:

Hue—7.5YR or 10YR
Value—2 to 4 dry; 2 or 3 moist
Chroma—1 or 2, dry or moist
Texture—coarse sand, loamy sand, or loamy coarse sand
Clay content—1 to 10 percent
Rock fragment content—60 to 87 percent cinders
Reaction—neutral or slightly alkaline

2Bw horizon:

Hue—7.5YR or 10YR
Value—3 to 5 dry; 3 or 4 moist
Chroma—3 to 6, dry or moist
Texture—sandy clay loam or sandy loam
Clay content—18 to 25 percent
Rock fragment content—60 to 85 percent cinders
Reaction—neutral or slightly alkaline

2C horizon:

Hue—7.5YR or 10YR
Value—2 to 4 dry; 2 or 3 moist
Chroma—1 to 4, dry or moist
Texture—sandy loam
Clay content—12 to 18 percent
Calcium carbonate equivalent—0 to 2 percent
Rock fragment content—35 to 55 percent cinders
Reaction—neutral or slightly alkaline

30—Sunsetcrater extremely gravelly loamy sand, 15 to 35 percent slopes

Map Unit Setting

Landform(s): Cinder cones (fig. 57)
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Mean annual precipitation: 18 to 22 inches (457 to 559 millimeters)
Mean annual air temperature: 42 to 46 degrees F (5.5 to 7.7 degrees C)
Mean annual soil temperature: 44 to 48 degrees F (6.6 to 8.8 degrees C)
Frost-free period: 100 to 120 days
Major land resource area: 39—Arizona and New Mexico Mountains
Land resource unit: 39-1 Mogollon Plateau-Coniferous Forest

Map Unit Composition

Sunsetcrater and similar soils: 100 percent

Description of the Sunsetcrater Soil

Taxonomic classification: Ashy-skeletal, glassy, frigid Vitrandic Haplustepts
Taxon kind: Series
Geomorphic position: Backslopes of cinder cones
Parent material: Tephra derived from volcanic rock over clayey tephra derived from volcanic rock
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Slope: 15 to 35 percent
Drainage class: Well drained



Figure 57.—An area of Sunsetcrater extremely gravelly loamy sand, 15 to 35 percent slopes.

K_{sat} of solum: 0.57 inch to 99.92 inches per hour (4.00 to 705.00 micrometers per second)

Available water capacity (total inches): 2.3 (very low)

Shrink-swell potential: About 4.5 LEP (moderate)

Flooding hazard: None

Ponding hazard: None

Runoff class: Low

Hydrologic group: B

Ecological site name: Cinder Cones 17-22" p.z.

Ecological site number: R039XA143AZ

Present vegetation: Ponderosa pine, rabbitbrush, muttongrass, Canada wildrye, and penstemon

Land capability classification (nonirrigated areas): 8c

Surface cover: (fig. 58)

Canopy plant cover—26 percent

Woody debris—0 percent

Herbaceous litter—96 percent

Bare soil—0 percent

Rock fragments—100 percent cinders

Typical Pedon (figs. 59 and 60)

Location by Universal Transverse Mercator System: Zone 12N, 3913204 Northing, 451533 Easting

C1—0 to 2 inches (0 to 5 centimeters); very dark gray (7.5YR 3/1) extremely gravelly loamy sand, black (7.5YR 2.5/1) moist; 6 percent clay; single grain; loose,

- nonsticky and nonplastic; many very fine roots throughout; 84 percent cinders; noneffervescent; slightly alkaline, pH 7.6; clear smooth boundary.
- C2—2 to 7 inches (5 to 18 centimeters); dark gray (7.5YR 4/1) extremely gravelly loamy sand, very dark gray (7.5YR 3/1) moist; 7 percent clay; weak fine granular structure; loose, nonsticky and nonplastic; many very fine, fine, and medium roots throughout; few very fine irregular pores; 65 percent cinders; noneffervescent; slightly alkaline, pH 7.4; abrupt smooth boundary.
- C3—7 to 12 inches (18 to 30 centimeters); very dark gray (7.5YR 3/1) extremely gravelly coarse sand, black (7.5YR 2.5/1) moist; 5 percent clay; single grain; loose, nonsticky and nonplastic; many very fine, fine, and medium roots throughout; 88 percent cinders; noneffervescent; slightly alkaline, pH 7.4; abrupt wavy boundary.
- 2Bw—12 to 21 inches (30 to 53 centimeters); brown (7.5YR 5/4) very gravelly sandy clay loam, brown (7.5YR 4/4) moist; 26 percent clay; moderate fine subangular blocky structure; slightly hard, very friable, moderately sticky and moderately plastic; many very fine, fine, medium, and coarse roots throughout; many very fine and fine tubular pores; 53 percent cinders; noneffervescent; slightly alkaline, pH 7.6; abrupt wavy boundary.
- 2C—21 to 60 inches (53 to 152 centimeters); light brown (7.5YR 6/4) and very dark gray (7.5YR 3/1) extremely gravelly loamy sand, brown (7.5YR 4/4) and black (7.5YR 2.5/1) moist; 8 percent clay; single grain; loose, nonsticky and nonplastic; common very fine and few fine roots throughout; 84 percent cinders; noneffervescent; slightly alkaline, pH 7.6.

Range in Characteristics

Rock fragments in the control section: 35 to 85 percent cinders



Figure 58.—The Sunsetcrater soil has an extremely gravelly loamy sand surface.



Figure 59.—Profile of Sunsetcrater soil. Scale is in centimeters.

Clay content of particle-size control section: 1 to 30 percent

Volcanic glass content: 30 to 40 percent

Cambic horizon: Zone between depths of 12 and 21 inches (30 and 53 centimeters)

C horizon:

Hue—5YR or 7.5YR

Value—2.5 to 4 dry; 2.5 or 3 moist

Chroma—1 or 2, dry or moist

Texture—coarse sand or loamy sand

Clay content—1 to 10 percent

Rock fragment content—60 to 88 percent cinders

Reaction—neutral or slightly alkaline

2Bw horizon:

Hue—5YR or 7.5YR

Value—3 to 5 dry; 3 or 4 moist

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Chroma—3 or 4, dry or moist
Texture—sandy clay loam
Clay content—20 to 30 percent
Rock fragment content—35 to 55 percent cinders
Reaction—neutral or slightly alkaline

2C horizon:

Hue—5YR or 7.5YR
Value—3 to 6 dry; 3 or 4 moist
Chroma—1 to 4, dry or moist
Texture—loamy sand
Clay content—2 to 10 percent
Rock fragment content—60 to 88 percent cinders
Reaction—neutral or slightly alkaline



Figure 60.—Box sample of Sunsetcrater typical profile.

Ecological Sites

Jennifer M. Puttere, ecological site inventory specialist, Natural Resources Conservation Service, prepared this section.

There are four ecological sites within Sunset Crater Volcano National Monument. Three of them have their type locations in the park. These sites are in major land resource area (MLRA) 39—Arizona and New Mexico Mountains and have an elevational range of about 7,000 to 12,000 feet. Dominant overstory vegetation throughout the majority of the park is ponderosa pine (*Pinus ponderosa*) with a shrubby understory of Apache plume (*Fallugia paradoxa*). The ecological sites in the park are considered range sites as their park-like structure is open and canopy covers are measured at less than 25 percent. The soil temperature regime is mesic to frigid, and the soil moisture regime ranges from typic ustic to udic ustic. MLRA 39 is limited to the Mogollon Plateau Coniferous Forests of Arizona and includes the City of Flagstaff, Arizona.

An ecological site description is a document that contains details about the characteristic soils, plant community, different ecological states and transitions that are expected, and site interpretations. For full ecological site descriptions that include a state and transition model, refer to the Natural Resources Conservation Service Ecological Site and Information System: <https://esis.sc.egov.usda.gov>. The ecological sites in Sunset Crater Volcano National Monument are briefly described in this section.

Every soil component is assigned to a rangeland or riparian ecological site classification. Ecological sites are the fundamental unit of a potential-based land classification system. Their purpose is to classify similar types of land based on their ability to produce particular plant communities which respond similarly to management. For rangelands, ecological sites are correlated to soil components based on the potential of the soil component to produce a particular kind and amount of vegetation that responds in a certain way to disturbance and management. For riparian areas, ecological sites are also correlated to soil components; however the correlation is based on associated valley types and stream types that produce a distinctive complex of riparian plant communities that respond in a certain way to disturbance and management.

Ecological site classifications on rangelands are defined primarily by their soil-geomorphic and climate features, which are the primary determinants of the native plant communities that a site is capable of supporting. In particular, the potential native plant communities differ among ecological sites as a result of soil features (such as texture, depth to restrictive layer, chemistry, subsurface horizons, and percent rock fragments) and topographic features (such as elevation, slope, aspect, and landscape position) within a particular climate zone. Each soil component is correlated to one ecological site within this soil survey. However, an ecological site may be correlated to more than one soil component as long as the potential vegetation and response to disturbance are similar among soil components.

Rangeland is typically defined as a type of land that supports vegetation suitable for grazing (grasses, forbs, and shrubs) and that is managed by ecological, rather than agronomic, methods. However, for this survey, the term rangeland is used to describe

all land that produces rangeland or woodland vegetation and is managed by ecological rather than agronomic methods.

Ecological site classifications in riparian areas differ from rangelands because they are influenced primarily by water flowing in an adjacent stream rather than inherent soil features. Riparian complex ecological sites are defined by concepts of fluvial geomorphology, which classifies streams based on valley type and stream type designations. The Rosgen stream classification system is used to define riparian complex ecological sites.

The correlation of riparian complex ecological sites to soil components is based on the valley type and stream type of the riparian system. Since valley type and stream type information is not generally included in soil map unit descriptions, the correlation is often coincidental, without reference to any particular soil features. Riparian complex ecological sites are capable of producing multiple plant communities, which are each influenced by horizontal distance to the stream and vertical distance to ground water. These plant communities typically occur in a linear pattern, with different plant communities occurring on stream banks, flood plains, and terraces as you move further from the stream channel.

Definition of Table Headers and Discussion of Data

Table 7—Ecological Site-Soil Correlation

This table lists the map unit symbol, soil name (component), and component percent with the ecological site name, ecological site type (forestland or rangeland), and ecological site ID (ecological site number).

Table 8—Climate, Landscape, Landform, Parent Material, and Ecological Site

This table displays information about climate, landscape, landform, parent material, and ecological site for each soil in the map units.

Percent of map unit is the extent of the named soil in the map unit.

Slope is the inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance. The table shows the low and high range of slope for the named component or soil.

Elevation is the height of an object or area on the earth's surface in reference to a fixed reference point, such as mean sea level. The typical low and high range of elevation is displayed for each soil.

MAP is the mean annual precipitation for areas of the soil in the map unit.

Landscape refers to the broad shape of the earth in the area where the soil occurs. Examples are a valley and a mountain.

Landform is a specific shape of the earth in the area where a soil typically occurs. Examples are a mountain summit and a valley bottom.

Parent material is the material in which soils formed. Examples are the underlying geological material (including bedrock), a surficial deposit (such as volcanic ash), and organic material. Soils inherit their chemical and physical properties from the parent material.

Ecological site and number is the ecological site name and unique reference number that are correlated to the named soil in the map unit.

Table 9—Rangeland Productivity and Characteristic Plant Communities

This table includes details for each map unit component suitable for rangeland, including the ecological site; estimated total annual production of the existing vegetation in favorable, normal, and unfavorable years; existing vegetation at the

time the survey; and typical percentage of dominant species measured by annual production.

Total production is the amount of vegetation that can be expected to grow annually in a well managed area that supports the existing plant community at the time of the survey. It includes all current year's vegetative growth of leaves, twigs, flowers, and fruits, whether or not it is palatable to grazing animals. It does not include the increase in stem diameter of trees and shrubs. Estimated total annual production values, in pounds per acre of air-dry vegetation, is given for favorable, normal, and unfavorable years. In a favorable year, the amount and distribution of precipitation and the temperatures make growing conditions substantially better than average. In a normal year, growing conditions are about average. In an unfavorable year, growing conditions are well below average, generally because of low available soil moisture. Yields are adjusted to a common percent of air-dry moisture content.

Characteristic plants reports the dominant grasses, forbs, shrubs and trees by annual production of the existing plant community at the time of the survey.

Composition gives the typical percentage of the total annual production for the dominant species of the existing vegetation. The amount that can be used as forage depends on the grazing animals and grazing season.

Information about rangeland management, including range similarity index and rangeland trend, is available in chapter 4 of the "National Range and Pasture Handbook," available on the Internet at <http://www.glti.nrcs.usda.gov/technical/publications/nrph.htm>.

Table 10—Canopy Cover

This table gives the canopy cover for the plant species associated with the map unit components. Canopy cover is determined by crown perimeter-vertical projection by species. Because this cover can overlap in layers by species, total cover can be greater than 100 percent.

Table 11—Index of Common and Scientific Plant Names and Plant Symbols

This table shows the common plants in the survey area and their associated scientific name and plant symbol.

Descriptions of Rangeland Ecological Sites

R039XA141AZ—Cindery-Ashy Upland 17-22" p.z.

This ecological site occurs on cinder cones and lava fields. The soils are very deep and well drained to excessively drained (fig. 61). Surface layers include extremely gravelly coarse sand, very gravelly loamy sand, extremely gravelly sand, and extremely gravelly loamy sand as cinders and ash. Subsurface layers are cindery and ashy-skeletal. The available water capacity is moderate. This site is at elevations between 6,750 and 8,039 feet (2,057 to 2,450 meters) on all aspects. Slopes range from 1 to 60 percent.

Mean annual precipitation ranges from 22 to 26 inches (559 to 660 millimeters), and mean annual temperature is between 39 and 45 degrees F (3.9 and 7.2 degrees C) (see table 8). The dominant vegetation on this site is ponderosa pine (*Pinus ponderosa*). The subdominant shrub understory consists mainly of Apache plume (*Fallugia paradoxa*) with a few scattered warm-season grasses, such as sand bluestem (*Andropogon hallii*) and blue grama (*Bouteloua gracilis*). See the state and transition model (fig. 62).

The reference state phase 1.1 of the Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ) site occurs in cinder fields below cinder cones (fig. 63). The surface

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Ecological Site Name	Map Unit Number	General Location	State	Phase
R039XA141AZ Cindery-Ashy Upland 17-22" p.z.				
	20	Sunset Crater National Monument	1	1.1
	20	Sunset Crater National Monument	1	1.2
	21	Sunset Crater National Monument	1	1.2
	24	Sunset Crater National Monument	1	1.2
	29	Sunset Crater National Monument	1	1.3

Figure 61.—Summary of soil map units that occur in ecological site R039XA141AZ—Cindery-Ashy Upland 17-22" p.z. in Sunset Crater Volcano National Monument. The state and phase columns refer to the included state and transition model.

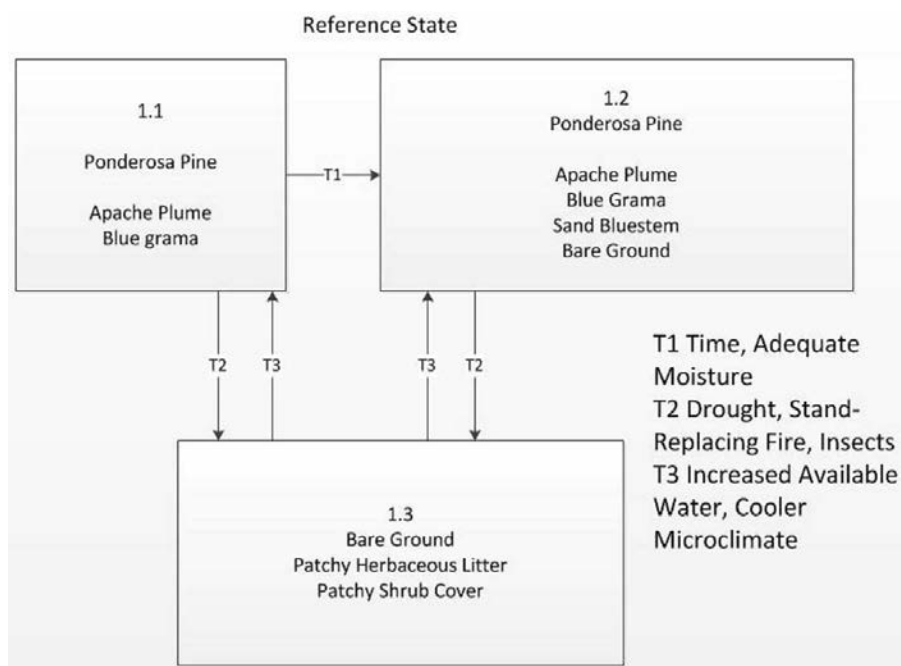


Figure 62.—State and transition model for R039XA141AZ—Cindery-Ashy Upland 17-22" p.z. in Sunset Crater Volcano National Monument.

cover is nearly 100 percent tephra. This site formed as a result of the eruption of Sunset Crater approximately 950 years ago. The soils are not well developed. Much of the area is lightly vegetated or nonvegetated. The dominant vegetation on this site is ponderosa pine (*Pinus ponderosa*), Apache plume (*Fallugia paradoxa*), sand bluestem (*Andropogon hallii*), and blue grama (*Bouteloua gracilis*). This is the most developed site in this ecological site model. As soil development progresses, blue grama increases.

In recent years, there has been an increase in bark beetle activity (*Ips* species) (Kanaly et al., 2006). This may be due to a number of factors. While there is some evidence of bark beetle damage in the park and on this ecological site in particular, it does not appear to be currently threatening to stands.

Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ), phase 1.2 occurs in depositional areas below cinder cones (fig. 64). Characteristics of this phase include scattered



Figure 63.—Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ), reference state phase 1.1. This photo shows ponderosa pine (*Pinus ponderosa*), blue grama (*Bouteloua gracilis*), and the colonizer sand bluestem (*Andropogon hallii*) codominated by Apache plume (*Fallugia paradoxa*) with pine needle litter.

ponderosa pine (*Pinus ponderosa*); sparse shrubs, including Apache plume (*Fallugia paradoxa*); and, in some areas, wax currant (*Ribes cereum*). Twoneedle pinyon (*Pinus edulis*) may also occur on this site. There is an observed increase in blue grama (*Bouteloua gracilis*) on this phase with a decrease in sand bluestem (*Andropogon hallii*), a frequent early colonizer that decreases as site stability increases. This decline in colonizer species may indicate an increase in site stability and an increase in soil organic matter (Shay et al., 2000).

Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ), phase 1.3 is the least developed phase in this ecological site model. A deep tephra layer limits the establishment of seedlings (fig. 65). In addition, the dark cinder color may heat the surface and prevent the survival of seedlings as the warm season progresses.

R039XA142AZ—Cinders-Lava Flow Upland 17-22" p.z.

This ecological site is characterized by surface basaltic lava flow and tephra over lava fields and lava flows (fig. 66). The soils are shallow to very deep and well drained to excessively drained (fig. 67). Surface layers include very gravelly loamy sand, gravelly sand as cinders and ash, and organic materials. Subsurface layers are ashy or ashy-skeletal. The available water capacity is moderate or high. This site is at elevations between 6,829 and 7,030 feet (2,081 and 2,143 meters) on all aspects. Slopes range from 2 to 15 percent.

Mean annual precipitation ranges from 22 to 26 inches (559 to 660 millimeters), and mean annual temperature is between 39 and 45 degrees F (3.9 and 7.2 degrees C) (see table 8). The dominant plants on this site include ponderosa pine (*Pinus*



Figure 64.—Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ), phase 1.2. Increased bare ground and decreased amounts of shrubs and herbaceous species distinguish this site. This site is younger and less well developed than phase 1.1, as indicated by the decrease in observed herbaceous species.



Figure 65.—Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ), phase 1.3. This site is dominated by bare ground with patchy areas of litter and shrubs. The phase 1.2 site with ponderosa pine (*Pinus ponderosa*) is in the background.



Figure 66.—Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ), state 1 is characterized by an overstory of ponderosa pine (*Pinus ponderosa*) with a shrub understory of Apache plume (*Fallugia paradoxa*). This site is covered by tephra interspersed with basaltic lava flow.

Ecological Site Name	Map Unit Number	General Location	State	Phase
R039XA142AZ Cinders-Lava Flow Upland 17-22" p.z				
	28	Bonito Lava Flow Area	1	1.1
	27	Bonito Lava Flow Area	2	2.1

Figure 67.—Summary of soil map units in Sunset Crater Volcano National Monument that occur in ecological site Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ). The state and phase columns refer to the included state and transition model.

ponderosa) and Apache plume (*Fallugia paradoxa*). Herbaceous species are limited and will likely increase as the soil develops and the site stabilizes. Some areas may have twoneedle pinyon (*Pinus edulis*) and wax currant (*Ribes cereum*) as early colonizers on the edges of the lava flows. See the state and transition model (fig. 68).

State 2, phase 2.1 of the Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ) site is characterized by the Bonito Lava Flow from Sunset Crater (fig. 69). This state is characterized as an 'a' lava flow with no soil development. There are pockets of herbaceous litter that have accumulated in low areas within the lava flow. These areas allow opportunistic species to germinate and grow in the lava flow in the absence of any soil development.

Aspen (*Populus tremuloides*) generally occur in an elevational range higher than that at the base of the cinder cones in the park. In Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ), state 2, phase 2.2, however, gaps in the lava cold-air pockets collect extra moisture and allow the aspen to grow at lower elevations (fig. 70). These

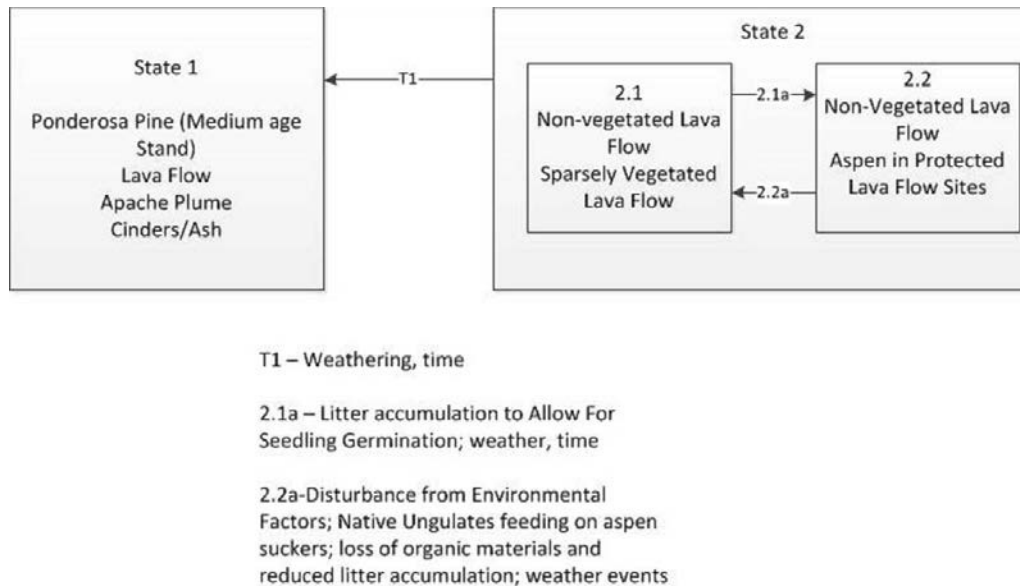


Figure 68.—State and transition model for R039XA142AZ—Cinders-Lava Flow Upland 17-22” p.z.

aspen are also protected from wildlife since these gaps are largely inaccessible to large grazers, such as elk.

R039XA143AZ—Cinder Cones 17-22” p.z.

The cinder cones on Sunset Crater are the most noticeable feature in Sunset Crater Volcano National Monument (figs. 71, 72, and 73). Several different observed phases of Cinder Cone sites occur within the park, which is part of the larger San Francisco Volcanic Field of northern Arizona.

This ecological site occurs primarily on cinder cones and, in some areas, lava fields. The soils are very deep and well drained or excessively well drained (fig. 74). Surface layers include extremely gravelly coarse sand, extremely gravelly loamy sand, and very gravelly coarse sand as cinders and ash. Subsurface layers are cindery or ashy-skeletal. The available water capacity is moderate. This site is at elevations between 6,890 and 8,039 feet (2,100 and 2,450 meters) on all aspects. Slopes range from 1 to 60 percent.

Mean annual precipitation ranges from 22 to 26 inches (559 to 660 millimeters), and mean annual temperature is between 39 and 45 degrees F (3.9 and 7.2 degrees C) (see table 8).

Different phases of this ecological site occur in the park. The cinder cone phase represents vegetated cinder cones. The dominant vegetation in this phase is ponderosa pine (*Pinus ponderosa*) and Apache plume (*Fallugia paradoxa*). See the state and transition model (fig. 75).

Aspect and thickness of cinders may be contributing factors to the cinder cone sparse vegetation type (Eggler, 1962; Ort et al., 2008). Pockets of litter and sheltered areas may allow colonization in these deep cinder cones.

The hummocky phase (phase 1.1a) of the Cinder Cones 17-22” p.z. (R039XA143AZ) site formed as a result of wind moving and redepositing ash from the original volcanic eruption (figs. 76 and 77). Little vegetation grows in this phase, but there are sparse areas of Newberry’s twinpod (*Physaria newberryi*), buckwheat (*Eriogonum* spp.), and sand bluestem (*Andropogon hallii*).



Figure 69.—A nonvegetated lava flow in Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ), state 2, phase 2.1. Vegetation may grow in litter pockets that accumulate in low areas of the lava flow. Although minimal in development, these areas of accumulation are able to support limited vegetation.



Figure 70.—An example of Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ), state 2, phase 2.2 with aspen growing in cold-air pockets in Cinders-Lava Flow Upland 18-22".



Figure 71.—An area of Cinder Cones 17-22" p.z. (R039XA143AZ) on Sunset Crater in Sunset Crater Volcano National Monument.



Figure 72.—An area of Cinder Cones 17-22" p.z. (R039XA143AZ) on Lenox Crater in Sunset Crater Volcano National Monument.



Figure 73.—A view of Cinder Cones 17-22" p.z. (R039XA143AZ) ecological site from the unnamed cinder cone in Sunset Crater Volcano National Monument. The northeastern aspect looks out over the low-lying Painted Desert. The lightly vegetated area has a covering of coarse cinder fragments that becomes finer the further away they are from the cinder cone.

Ecological Site Name	Map Unit Number	General Location	State	Phase
R039XA143AZ Cinder Cones 17-22" p.z.	26	Sunset Crater National Monument	1	1.2a
	30	Sunset Crater National Monument	1	1.2c
	25	Sunset Crater National Monument	1	1.1
	22	Bonito Lava Flow Area	1	1.1

Figure 74.—Summary of soil map units in Sunset Crater Volcano National Monument that occur in ecological site Cinder Cones 17-22" p.z. (R039XA143AZ). The state and phase columns refer to the included state and transition model.

Thick cinders on Cinder Cones 17-22" p.z. (R039XA143AZ), state 1.2a (nonvegetated state) make it difficult for seedlings to establish on this site (fig. 78). A low water-holding capacity, rapid permeability, low availability of nutrients, and high daytime temperatures limit growth on this site (Ort et al., 2008). Shrubs are able to grow where there is a protective layer of litter accumulation and in sheltered areas where daytime temperatures are not as high and more moisture is available.

R039XA130AZ—Loamy Bottom 17-22" p.z.

This ecological site is limited to a small area in the park on the main road to the Visitor's Center (fig. 79). It is part of a larger ecological site that occurs on the eastern edge of Sunset Crater on the road from Highway 89 to the Visitor's Center. It occurs on playas that may occasionally flood. The soils are very deep and well drained (fig. 80). Surface layers include very gravelly sandy loam and extremely gravelly sandy loam.

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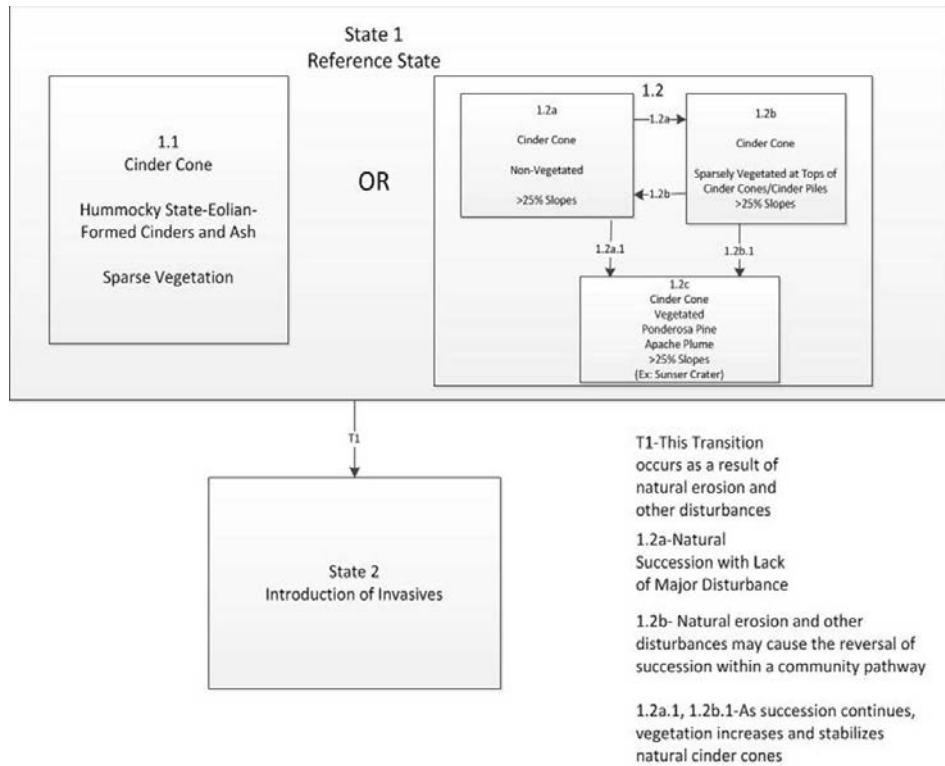


Figure 75.—State and transition model for ecological site R039XA143AZ—Cinder Cones 17-22” p.z.



Figure 76.—An area of Cinder Cones 17-22” p.z. (R039XA143AZ), state 1, phase 1.1a (hummocky phase).



Figure 77.—A sparsely vegetated cinder cone in Sunset Crater Volcano National Monument in ecological site Cinder Cones 17-22" p.z. (R039XA143AZ), state 1, phases 1.2a and 1.2b.



Figure 78.—Cinder Cones 17-22" p.z. (R039XA143AZ), state 1.2a (nonvegetated state) is the major component of this ecological site.



Figure 79.—Loamy Bottom 17-22" p.z. (R039XA130AZ). This ecological site occurs both inside and outside the park boundaries. The type location is outside the park.

Ecological Site Name	Map Unit Number	General Location	State	Phase
R039XA130AZ Loamy Bottom 17-22" p.z.	23	Bonito Park Area	1	1.1a

Figure 80.—Summary of soil map units in Sunset Crater Volcano National Monument that occur on the the Loamy Bottom 17-22" p.z. ecological site. The state and phase columns refer to the included state and transition model.

Subsurface layers are coarse. The available water capacity is moderate. This site is at elevations between 6,920 and 6,940 feet (2,110 and 2,115 meters) on all aspects. Slopes range from 0 to 2 percent.

Mean annual precipitation ranges from 22 to 26 inches (559 to 660 millimeters), and mean annual temperature is between 39 and 45 degrees F (3.9 and 7.2 degrees C). Dominant vegetation is warm-season grasses such as blue grama (*Bouteloua gracilis*), cool-season grasses such as Indian ricegrass (*Achnatherum hymenoides*), and a variety of perennial and annual forbs. See the state and transition model (fig. 81).

Summary and Conclusions

R039XA141AZ—Cindery-Ashy Upland 17-22" p.z. is characterized by ponderosa pine and Apache plume. While the site is dominated by ponderosa pine in some phases, in other phases it has little to no vegetation. This site is similar to the adjacent Cinders-Lava Flow Upland ecological site but differs in that it lacks any lava flow above the soil surface.

R039XA142AZ—Cinders-Lava Flow Upland 17-22" p.z. is characterized by tephra deposits interspersed with basaltic lava bedrock. Dominant vegetation is ponderosa

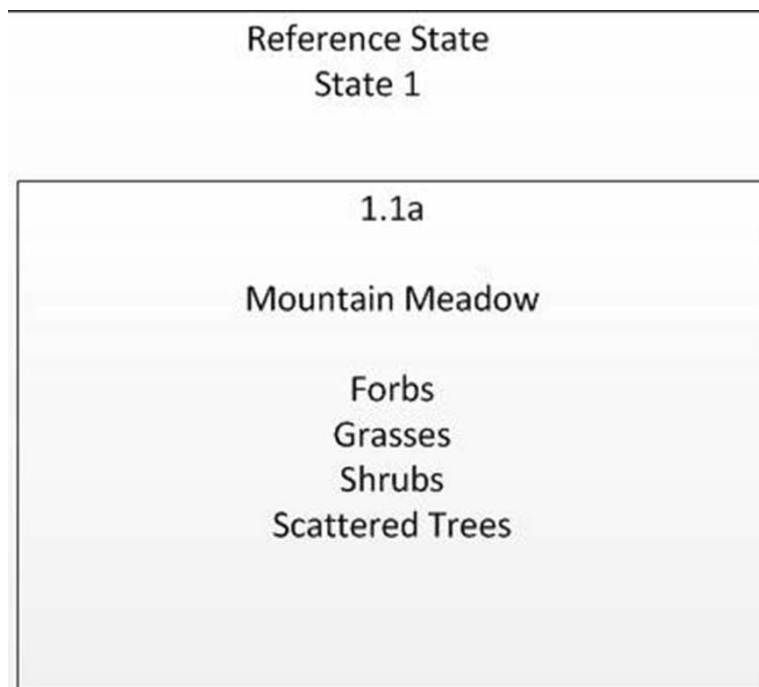


Figure 81.—State and transition model for ecological site R039XA130AZ—Loamy Bottom 17-22" p.z.

Ecological Site Name	MU Number			
R039XA141AZ Cindery-Ashy Upland 17-22" p.z.	20	21	24	29
R039XA143AZ Cinder Cones 17-22" p.z.	26	30	25	22
R039XA142AZ Cinders-Lava Flow Upland 17-22" p.z.	28	27		
R039XA130AZ Loamy Bottom 17-22" p.z.	23			

Figure 82.—Ecological sites and associated map units.

pine with a few warm-season grasses. The site may have natural cracks in the basalt bedrock in which aspen (*Populus tremuloides*) may grow.

R039XA143AZ—Cinder Cones 17-22" p.z. is characterized by cone-shaped mounds of ash and cinders formed by the extrusion of magma. This site may range from nearly flat or undulating to full cones with slopes up to 45 percent. Vegetation may also range from nearly none, to patchy, to nearly forested areas of ponderosa pine.

R039XA130AZ—Loamy Bottom 17-22" p.z. is characterized by flat mountain meadows dominated by annual and perennial forbs. Scattered areas of ponderosa pine may occur throughout the site.

Figure 82 shows which map units occur in each of the four ecological sites.

Use and Management of the Soils

This soil survey is an inventory and evaluation of the soils in the survey area. It can be used to adjust land uses to the limitations and potentials of natural resources and the environment. Also, it can help to prevent soil-related failures in land uses.

In preparing a soil survey, soil scientists, conservationists, engineers, and others collect extensive field data about the nature and behavioral characteristics of the soils. They collect data on erosion, droughtiness, flooding, and other factors that affect various soil uses and management. Field experience and collected data on soil properties and performance are used as a basis in predicting soil behavior.

Information in this section can be used to plan the use and management of soils for rangeland and forestland; as sites for buildings, sanitary facilities, highways and other transportation systems, and parks and other recreational facilities. It can be used to identify the potentials and limitations of each soil for specific land uses and to help prevent construction failures caused by unfavorable soil properties.

Planners and others using soil survey information can evaluate the effect of specific land uses on productivity and on the environment in all or part of the survey area. The survey can help planners to maintain or create a land use pattern in harmony with the natural soil.

Contractors can use this survey to locate sources of sand and gravel, roadfill, and topsoil. They can use it to identify areas where bedrock, wetness, or very firm soil layers can cause difficulty in excavation.

Interpretive Ratings

The interpretive tables in this survey rate the soils in the survey area for various uses. Many of the tables identify the limitations that affect specified uses and indicate the severity of those limitations. The ratings in these tables are both verbal and numerical.

Rating Class Terms

Rating classes are expressed in the tables in terms that indicate the extent to which the soils are limited by all of the soil features that affect a specified use or in terms that indicate the suitability of the soils for the use. Thus, the tables may show limitation classes or suitability classes. Terms for the limitation classes are *not limited*, *somewhat limited*, and *very limited*. The suitability ratings are expressed as *well suited*, *moderately suited*, *poorly suited*, and *unsuited* or as *good*, *fair*, and *poor*.

Numerical Ratings

Numerical ratings in the tables indicate the relative severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.00 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use and the point at which the soil feature is not a limitation. The limitations

appear in order from the most limiting to the least limiting. Thus, if more than one limitation is identified, the most severe limitation is listed first and the least severe one is listed last.

Land Capability Classification

Land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. Crops that require special management are excluded. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. The criteria used in grouping the soils do not include major and generally expensive landforming that would change slope, depth, or other characteristics of the soils, nor do they include possible but unlikely major reclamation projects. Capability classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for rangeland, for forestland, or for engineering purposes.

In the capability system, soils are generally grouped at three levels—capability class, subclass, and unit (USDA-SCS, 1961). Only class and subclass are used in this survey.

Capability classes, the broadest groups, are designated by the numbers 1 through 8. The numbers indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

Class 1 soils have slight limitations that restrict their use.

Class 2 soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices.

Class 3 soils have severe limitations that restrict the choice of plants or that require special conservation practices, or both.

Class 4 soils have very severe limitations that restrict the choice of plants or that require very careful management, or both.

Class 5 soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.

Class 6 soils have severe limitations that make them generally unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.

Class 7 soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to grazing, forestland, or wildlife habitat.

Class 8 soils and miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed, or esthetic purposes.

Capability subclasses are soil groups within one class. They are designated by adding a small letter, *e*, *w*, *s*, or *c*, to the class numeral, for example, 2*e*. The letter *e* shows that the main hazard is the risk of erosion unless close-growing plant cover is maintained; *w* shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c*, used in only some parts of the United States, shows that the chief limitation is climate that is very cold or very dry.

In class 1 there are no subclasses because the soils of this class have few limitations. Class 5 contains only the subclasses indicated by *w*, *s*, or *c* because the soils in class 5 are subject to little or no erosion. They have other limitations that restrict their use to pasture, rangeland, forestland, wildlife habitat, or recreation.

The capability classification of map units in this park is given in the section “Detailed Soil Map Units” and in table 12.

Prime Farmland

Prime farmland is one of several kinds of important farmland defined by the U.S. Department of Agriculture. It is of major importance in meeting the Nation's short- and long-range needs for food and fiber. Because the supply of high-quality farmland is limited, the U.S. Department of Agriculture recognizes that responsible levels of government, as well as individuals, should encourage and facilitate the wise use of our Nation's prime farmland.

Prime farmland, as defined by the U.S. Department of Agriculture, is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. It could be cultivated land, pastureland, forestland, or other land, but it is not urban or built-up land or water areas. The soil qualities, growing season, and moisture supply are those needed for the soil to economically produce sustained high yields of crops when proper management, including water management, and acceptable farming methods are applied. In general, prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, an acceptable salt and sodium content, and few or no rocks. It is permeable to water and air. It is not excessively erodible or saturated with water for long periods, and it either is not frequently flooded during the growing season or is protected from flooding. Slope ranges mainly from 0 to 6 percent. More detailed information about the criteria for prime farmland is available at the local office of the Natural Resources Conservation Service.

There are no areas in Sunset Crater Volcano National Monument that meet the soil requirements for prime farmland.

Hydric Soils

There are no hydric soils in the survey area. This section is provided for informational purposes.

The three essential characteristics of wetlands are hydrophytic vegetation, hydric soils, and wetland hydrology (Cowardin and others, 1979; U.S. Army Corps of Engineers, 1987; National Research Council, 1995; Tiner, 1985). Criteria for all of the characteristics must be met for areas to be identified as wetlands. Undrained hydric soils that have natural vegetation should support a dominant population of ecological wetland plant species. Hydric soils that have been converted to other uses should be capable of being restored to wetlands. Onsite investigation is recommended to determine the hydric soils on a specific site (National Research Council, 1995; USDA-NRCS, 2010).

Hydric soils are defined by the National Technical Committee for Hydric Soils (NTCHS) as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (Federal Register, 1994). These soils, under natural conditions, are either saturated or inundated long enough during the growing season to support the growth and reproduction of hydrophytic vegetation.

The NTCHS definition identifies general soil properties that are associated with wetness. In order to determine whether a specific soil is a hydric soil or nonhydric soil, however, more specific information, such as information about the depth and duration of the water table, is needed. Thus, criteria that identify those estimated soil properties unique to hydric soils have been established (Federal Register, 2002). These criteria are used to identify map unit components that normally are associated with wetlands. The criteria used are selected estimated soil properties that are described in "Soil Taxonomy" (Soil Survey Staff, 1999) and "Keys to Soil Taxonomy" (Soil Survey Staff, 2010) and in the "Soil Survey Manual" (Soil Survey Division Staff, 1993).

If soils are wet enough for a long enough period of time to be considered hydric, they should exhibit certain properties that can be easily observed in the field. These visible properties are indicators of hydric soils. The indicators used to make onsite determinations of hydric soils are specified in "Field Indicators of Hydric Soils in the United States" (USDA-NRCS, 2010).

Hydric soils are identified by examining and describing the soil to a depth of about 20 inches. This depth may be greater if determination of an appropriate indicator so requires. It is always recommended that soils be excavated and described to the depth necessary for an understanding of the redoximorphic processes. Then, using the completed soil descriptions, soil scientists can compare the soil features required by each indicator and specify which indicators have been matched with the conditions observed in the soil. The soil can be identified as a hydric soil if at least one of the approved indicators is present.

Map units that are dominantly made up of hydric soils may have small areas, or inclusions, of nonhydric soils in the higher positions on the landform, and map units dominantly made up of nonhydric soils may have inclusions of hydric soils in the lower positions on the landform.

Land Management

In table 13, parts I through IV, interpretive ratings are given for various aspects of land management. The ratings are both verbal and numerical.

Some rating class terms indicate the degree to which the soils are suited to a specified land management practice. *Well suited* indicates that the soil has features that are favorable for the specified practice and has no limitations. Good performance can be expected, and little or no maintenance is needed. *Moderately suited* indicates that the soil has features that are moderately favorable for the specified practice. One or more soil properties are less than desirable, and fair performance can be expected. Some maintenance is needed. *Poorly suited* indicates that the soil has one or more properties that are unfavorable for the specified practice. Overcoming the unfavorable properties requires special design, extra maintenance, and costly alteration. *Unsuited* indicates that the expected performance of the soil is unacceptable for the specified practice or that extreme measures are needed to overcome the undesirable soil properties.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the specified land management practice (1.00) and the point at which the soil feature is not a limitation (0.00).

Rating class terms for *fire damage* and *seedling mortality* are expressed as low, moderate, and high. Where these terms are used, the numerical ratings indicate gradations between the point at which the potential for fire damage or seedling mortality is highest (1.00) and the point at which the potential is lowest (0.00).

Rating class terms for *hazard of erosion* are expressed as slight, moderate, severe, and very severe. Where these terms are used, the numerical ratings indicate gradations between the point at which the potential for erosion is highest (1.00) and the point at which the potential is lowest (0.00).

The paragraphs that follow indicate the soil properties considered in rating the soils for land management practices.

Planting

Ratings in the columns *suitability for hand planting* and *suitability for mechanical planting* are based on slope, depth to a restrictive layer, content of sand, plasticity index, rock fragments on or below the surface, depth to a water table, and ponding. The soils are described as well suited, moderately suited, poorly suited, or unsuited to

these methods of planting. It is assumed that necessary site preparation is completed before seedlings are planted.

Ratings in the column *suitability for use of harvesting equipment* indicate the suitability of the soils for harvesting with heavy equipment. It assumes the use of standard rubber-tired skidders and bulldozers for ground-based harvesting and transport. It considers the off-road transport or harvest of logs and/or wood products by ground-based wheeled or tracked equipment. Activities that disturb from 35 to 75 percent of the surface area with rutting, puddling, or displacement up to a depth of 18 inches are also considered. Year-round water tables and year-round ponding are unfavorable. Ratings do not assess non-soil obstacles, such as slash, or frozen or snow-covered soils.

Hazard of Erosion and Suitability for Roads

Ratings in the column *hazard of off-road or off-trail erosion* indicate the hazard or risk of soil loss from soil due to after-disturbance activities that expose the soil surface. The ratings assess sheet and rill erosion from exposed soil surfaces caused by various silvicultural practices, mining, fire, and establishment of firebreaks. Additional hazardous activities include others that result in 50 to 75 percent bare ground in the disturbed area, the use of any type or size of equipment, and uncontrolled grazing by livestock. Ratings assume the exposure of 50 to 75 percent of the roughened mineral surface layer.

Ratings in the column *hazard of erosion on roads and trails* are based on the soil erodibility factor K, slope, and content of rock fragments. The ratings apply to unsurfaced roads and trails. The hazard is described as slight, moderate, or severe. A rating of *slight* indicates that little or no erosion is likely; *moderate* indicates that some erosion is likely, that the roads or trails may require occasional maintenance, and that simple erosion-control measures are needed; and *severe* indicates that significant erosion is expected, that the roads or trails require frequent maintenance, and that costly erosion-control measures are needed.

Ratings in the column *suitability for roads (natural surface)* are based on slope, rock fragments on the surface, plasticity index, content of sand, the Unified classification, depth to a water table, ponding, flooding, and the hazard of soil slippage. The ratings indicate the suitability for using the natural surface of the soil for roads. The soils are described as well suited, moderately suited, or poorly suited to this use.

Site Preparation

Ratings in the column *suitability for mechanical site preparation (deep)* are based on slope, depth to a restrictive layer, rock fragments on or below the surface, depth to a water table, and ponding. The soils are described as well suited, poorly suited, or unsuited to this management activity. The part of the soil from the surface to a depth of about 3 feet is considered in the ratings.

Ratings in the column *suitability for mechanical site preparation (surface)* are based on slope, depth to a restrictive layer, plasticity index, rock fragments on or below the surface, depth to a water table, and ponding. The soils are described as well suited, poorly suited, or unsuited to this management activity. The part of the soil from the surface to a depth of about 1 foot is considered in the ratings.

Site Restoration

Ratings in the column *potential for damage to soil by fire* are based on texture of the surface layer, content of rock fragments and organic matter in the surface layer, thickness of the surface layer, and slope. The soils are described as having a low, moderate, or high potential for this kind of damage. The ratings indicate an evaluation of the potential impact of prescribed fires or wildfires that are intense enough to remove the duff layer and consume organic matter in the surface layer.

Ratings in the column *potential for seedling mortality* are based on flooding, ponding, depth to a water table, content of lime, reaction, salinity, available water capacity, soil moisture regime, soil temperature regime, aspect, and slope. The soils are described as having a low, moderate, or high potential for seedling mortality.

Recreation

The soils of the park are rated in table 14, parts I and II, according to limitations that affect their suitability for recreation. The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the recreational uses. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The ratings in the table are based on restrictive soil features, such as wetness, slope, and texture of the surface layer. Susceptibility to flooding is considered. Not considered in the ratings, but important in evaluating a site, are the location and accessibility of the area, the size and shape of the area and its scenic quality, vegetation, access to water, potential water impoundment sites, and access to public sewer lines. The capacity of the soil to absorb septic tank effluent and the ability of the soil to support vegetation also are important. Soils that are subject to flooding are limited for recreational uses by the duration and intensity of flooding and the season when flooding occurs. In planning recreational facilities, onsite assessment of the height, duration, intensity, and frequency of flooding is essential.

The information in table 14 can be supplemented by other information in this survey, for example, interpretations for building site development, construction materials, and water management.

Camp areas require site preparation, such as shaping and leveling the tent and parking areas, stabilizing roads and intensively used areas, and installing sanitary facilities and utility lines. Camp areas are subject to heavy foot traffic and some vehicular traffic. The ratings are based on the soil properties that affect the ease of developing camp areas and the performance of the areas after development. Slope, stoniness, and depth to bedrock or a cemented pan are the main concerns affecting the development of camp areas. The soil properties that affect the performance of the areas after development are those that influence trafficability and promote the growth of vegetation, especially in heavily used areas. For good trafficability, the surface of camp areas should absorb rainfall readily, remain firm under heavy foot traffic, and not be dusty when dry. The soil properties that influence trafficability are texture of the surface layer, depth to a water table, ponding, flooding, permeability, and large stones. The soil properties that affect the growth of plants are depth to bedrock or a cemented pan, permeability, and toxic substances in the soil.

Picnic areas are subject to heavy foot traffic. Most vehicular traffic is confined to access roads and parking areas. The ratings are based on the soil properties that affect the ease of developing picnic areas and that influence trafficability and the growth of vegetation after development. Slope and stoniness are the main concerns affecting the development of picnic areas. For good trafficability, the surface of picnic

areas should absorb rainfall readily, remain firm under heavy foot traffic, and not be dusty when dry. The soil properties that influence trafficability are texture of the surface layer, depth to a water table, ponding, flooding, permeability, and large stones. The soil properties that affect the growth of plants are depth to bedrock or a cemented pan, permeability, and toxic substances in the soil.

Foot traffic and equestrian trails for hiking and horseback riding should require little or no slope modification through cutting and filling. The ratings are based on the soil properties that affect trafficability and erodibility. These properties are stoniness, depth to a water table, ponding, flooding, slope, and texture of the surface layer.

Mountain bike and off-road vehicle trails require little or no site preparation. They are not covered with surfacing material or vegetation. Considerable compaction of the soil material is likely. The ratings are based on the soil properties that influence erodibility, trafficability, dustiness, and the ease of revegetation. These properties are stoniness, depth to a water table, ponding, slope, flooding, and texture of the surface layer.

Engineering

This section provides information for planning land uses related to urban development and to water management. Soils are rated for various uses, and the most limiting features are identified. Ratings are given for building site development, sanitary facilities, construction materials, and water management. The ratings are based on observed performance of the soils and on the data in the tables described under the heading "Soil Properties."

Information in this section is intended for land use planning, for evaluating land use alternatives, and for planning site investigations prior to design and construction. The information, however, has limitations. For example, estimates and other data generally apply only to that part of the soil between the surface and a depth of 5 to 7 feet. Because of the map scale, small areas of different soils may be included within the mapped areas of a specific soil.

The information is not site-specific and does not eliminate the need for onsite investigation of the soils or for testing and analysis by personnel experienced in the design and construction of engineering works.

Government ordinances and regulations that restrict certain land uses or impose specific design criteria were not considered in preparing the information in this section. Local ordinances and regulations should be considered in planning, in site selection, and in design.

Soil properties, site features, and observed performance were considered in determining the ratings in this section. During the fieldwork for this soil survey, determinations were made about particle-size distribution, liquid limit, plasticity index, soil reaction, depth to bedrock, hardness of bedrock within 5 to 7 feet of the surface, soil wetness, depth to a water table, ponding, slope, likelihood of flooding, natural soil structure aggregation, and soil density. Data were collected about kinds of clay minerals, mineralogy of the sand and silt fractions, and the kinds of adsorbed cations. Estimates were made for erodibility, permeability, corrosivity, shrink-swell potential, available water capacity, and other behavioral characteristics affecting engineering uses.

This information can be used to evaluate the potential of areas for residential, commercial, industrial, and recreational uses; make preliminary estimates of construction conditions; evaluate alternative routes for roads, streets, highways, pipelines, and underground cables; evaluate alternative sites for septic tank absorption fields and sewage lagoons; plan detailed onsite investigations of soils and geology; locate potential sources of gravel, sand, earthfill, and topsoil; plan drainage systems, irrigation systems, ponds, terraces, and other structures for soil and water

conservation; and predict performance of proposed small structures and pavements by comparing the performance of existing similar structures on the same or similar soils.

The information in the tables, along with the soil map, the soil descriptions, and other data provided in this survey, can be used to make additional interpretations.

Some of the terms used in this soil survey have a special meaning in soil science and are defined in the Glossary.

Dwellings and Small Commercial Buildings

Soil properties influence the development of building sites, including the selection of the site, the design of the structure, construction, performance after construction, and maintenance. Table 15 shows the degree and kind of soil limitations that affect dwellings and small commercial buildings.

The ratings in the table are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect building site development. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Dwellings are single-family houses of three stories or less. For dwellings without basements, the foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of 2 feet or at the depth of maximum frost penetration, whichever is deeper. For dwellings with basements, the foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of about 7 feet. The ratings for dwellings are based on the soil properties that affect the capacity of the soil to support a load without movement and on the properties that affect excavation and construction costs. The properties that affect the load-supporting capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility. Compressibility is inferred from the Unified classification. The properties that affect the ease and amount of excavation include depth to a water table, ponding, flooding, slope, depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, and the amount and size of rock fragments.

Small commercial buildings are structures that are less than three stories high and do not have basements. The foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of 2 feet or at the depth of maximum frost penetration, whichever is deeper. The ratings are based on the soil properties that affect the capacity of the soil to support a load without movement and on the properties that affect excavation and construction costs. The properties that affect the load-supporting capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility (which is inferred from the Unified classification). The properties that affect the ease and amount of excavation include flooding, depth to a water table, ponding, slope, depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, and the amount and size of rock fragments.

Roads and Streets, Shallow Excavations, and Landscaping

Soil properties influence the development of building sites, including the selection of the site, the design of the structure, construction, performance after construction, and maintenance. Table 16 shows the degree and kind of soil limitations that affect local roads and streets, shallow excavations, and landscaping.

The ratings in the table are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect building site development. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Local roads and streets have an all-weather surface and carry automobile and light truck traffic all year. They have a subgrade of cut or fill soil material; a base of gravel, crushed rock, or soil material stabilized by lime or cement; and a surface of flexible material (asphalt), rigid material (concrete), or gravel with a binder. The ratings are based on the soil properties that affect the ease of excavation and grading and the traffic-supporting capacity. The properties that affect the ease of excavation and grading are depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, depth to a water table, ponding, flooding, the amount of large stones, and slope. The properties that affect the traffic-supporting capacity are soil strength (as inferred from the AASHTO group index number), subsidence, linear extensibility (shrink-swell potential), the potential for frost action, depth to a water table, and ponding.

Shallow excavations are trenches or holes dug to a maximum depth of 5 or 6 feet for graves, utility lines, open ditches, or other purposes. The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing. Depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, the amount of large stones, and dense layers influence the ease of digging, filling, and compacting. Depth to the seasonal high water table, flooding, and ponding may restrict the period when excavations can be made. Slope influences the ease of using machinery. Soil texture, depth to the water table, and linear extensibility (shrink-swell potential) influence the resistance to sloughing.

Landscaping requires soils on which turf, trees, and shrubs can be established and maintained. Irrigation is not considered in the ratings. The ratings are based on the soil properties that affect plant growth and trafficability after vegetation is established. The properties that affect plant growth are reaction; depth to a water table; ponding; depth to bedrock or a cemented pan; the available water capacity in the upper 40 inches; the content of salts, sodium, or calcium carbonate; and sulfidic materials. The properties that affect trafficability are flooding, depth to a water table, ponding, slope, stoniness, and the amount of sand, clay, or organic matter in the surface layer.

Sewage Disposal

Table 17 shows the degree and kind of soil limitations that affect septic tank absorption fields and sewage lagoons. The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil

features that affect these uses. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Septic tank absorption fields are areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe. Only that part of the soil between depths of 24 and 72 inches or between a depth of 24 inches and a restrictive layer is evaluated. The ratings are based on the soil properties that affect absorption of the effluent, construction and maintenance of the system, and public health. Saturated hydraulic conductivity (K_{sat}), depth to a water table, ponding, depth to bedrock or a cemented pan, and flooding affect absorption of the effluent. Stones and boulders, ice, and bedrock or a cemented pan interfere with installation. Subsidence interferes with installation and maintenance. Excessive slope may cause lateral seepage and surfacing of the effluent in downslope areas.

Some soils are underlain by loose sand and gravel or fractured bedrock at a depth of less than 4 feet below the distribution lines. In these soils the absorption field may not adequately filter the effluent, particularly when the system is new. As a result, the ground water may become contaminated.

Sewage lagoons are shallow ponds constructed to hold sewage while aerobic bacteria decompose the solid and liquid wastes. Lagoons should have a nearly level floor surrounded by cut slopes or embankments of compacted soil. Nearly impervious soil material for the lagoon floor and sides is required to minimize seepage and contamination of ground water. Considered in the ratings are slope, saturated hydraulic conductivity (K_{sat}), depth to a water table, ponding, depth to bedrock or a cemented pan, flooding, large stones, and content of organic matter.

Saturated hydraulic conductivity (K_{sat}) is a critical property affecting the suitability for sewage lagoons. Most porous soils eventually become sealed when they are used as sites for sewage lagoons. Until sealing occurs, however, the hazard of pollution is severe. Soils that have a K_{sat} rate of more than 14 micrometers per second are too porous for the proper functioning of sewage lagoons. In these soils, seepage of the effluent can result in contamination of the ground water. Ground-water contamination is also a hazard if fractured bedrock is within a depth of 40 inches, if the water table is high enough to raise the level of sewage in the lagoon, or if floodwater overtops the lagoon.

A high content of organic matter is detrimental to proper functioning of the lagoon because it inhibits aerobic activity. Slope, bedrock, and cemented pans can cause construction problems, and large stones can hinder compaction of the lagoon floor. If the lagoon is to be uniformly deep throughout, the slope must be gentle enough and the soil material must be thick enough over bedrock or a cemented pan to make land smoothing practical.

Source of Gravel and Sand

Table 18 gives information about the soils as potential sources of gravel and sand. Normal compaction, minor processing, and other standard construction practices are assumed.

Gravel and *sand* are natural aggregates suitable for commercial use with a minimum of processing. They are used in many kinds of construction. Specifications for each use vary widely. Only the likelihood of finding material in suitable quantity is evaluated. The suitability of the material for specific purposes is not evaluated, nor are factors that affect excavation of the material. The properties used to evaluate the soil as a source of sand or gravel are gradation of grain sizes (as indicated by the Unified classification of the soil), the thickness of suitable material, and the content of rock fragments. If the bottom layer of the soil contains sand or gravel, the soil is considered a likely source regardless of thickness. The assumption is that the sand or gravel layer below the depth of observation exceeds the minimum thickness. The ratings are for the whole soil, from the surface to a depth of about 6 feet.

The soils are rated *good*, *fair*, or *poor* as potential sources of sand and gravel. A rating of *good* or *fair* means that the source material is likely to be in or below the soil. The bottom layer and the thickest layer of the soils are assigned numerical ratings. These ratings indicate the likelihood that the layer is a source of sand or gravel. The number 0.00 indicates that the layer is a poor source. The number 1.00 indicates that the layer is a good source. A number between 0.00 and 1.00 indicates the degree to which the layer is a likely source.

Source of Reclamation Material, Roadfill, and Topsoil

Table 19 gives information about the soils as potential sources of reclamation material, roadfill, and topsoil. Normal compaction, minor processing, and other standard construction practices are assumed.

The soils are rated *good*, *fair*, or *poor* as potential sources of reclamation material, roadfill, and topsoil. The features that limit the soils as sources of these materials are specified in the table. Numerical ratings between 0.00 and 0.99 are given after the specified features. These numbers indicate the degree to which the features limit the soils as sources of topsoil, reclamation material, or roadfill. The lower the number, the greater the limitation.

Reclamation material is used in areas that have been drastically disturbed by surface mining or similar activities. When these areas are reclaimed, layers of soil material or unconsolidated geological material, or both, are replaced in a vertical sequence. The reconstructed soil favors plant growth. The ratings in the table do not apply to quarries and other mined areas that require an offsite source of reconstruction material. The ratings are based on the soil properties that affect erosion and stability of the surface and the productive potential of the reconstructed soil. These properties include the content of sodium, salts, and calcium carbonate; reaction; available water capacity; erodibility; texture; content of rock fragments; and content of organic matter and other features that affect fertility.

Roadfill is soil material that is excavated in one place and used in road embankments in another place. In this table, the soils are rated as a source of roadfill for low embankments, generally less than 6 feet high and less exacting in design than higher embankments. The ratings are for the whole soil, from the surface to a depth of about 5 feet. It is assumed that soil layers will be mixed when the soil material is excavated and spread.

The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place. The thickness of the suitable material is a major consideration. The ease of excavation is affected by large stones, depth to a water table, and slope. How well the soil performs in place after it has been compacted and drained is determined by its strength (as inferred from the AASHTO classification of the soil) and linear extensibility (shrink-swell potential).

Topsoil is used to cover an area so that vegetation can be established and maintained. The upper 40 inches of a soil is evaluated for use as topsoil. Also

evaluated is the reclamation potential of the borrow area. The ratings are based on the soil properties that affect plant growth; the ease of excavating, loading, and spreading the material; and reclamation of the borrow area. Toxic substances, soil reaction, and the properties that are inferred from soil texture, such as available water capacity and fertility, affect plant growth. The ease of excavating, loading, and spreading is affected by rock fragments, slope, depth to a water table, soil texture, and thickness of suitable material. Reclamation of the borrow area is affected by slope, depth to a water table, rock fragments, depth to bedrock or a cemented pan, and toxic material.

The surface layer of most soils is generally preferred for topsoil because of its organic matter content. Organic matter greatly increases the absorption and retention of moisture and nutrients for plant growth.

Ponds and Embankments

Table 20 gives information on the soil properties and site features that affect water management. The degree and kind of soil limitations are given for pond reservoir areas; embankments, dikes, and levees; and aquifer-fed excavated ponds. The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Pond reservoir areas hold water behind a dam or embankment. Soils best suited to this use have low seepage potential in the upper 60 inches. The seepage potential is determined by the saturated hydraulic conductivity (K_{sat}) of the soil and the depth to fractured bedrock or other permeable material. Excessive slope can affect the storage capacity of the reservoir area.

Embankments, dikes, and levees are raised structures of soil material, generally less than 20 feet high, constructed to impound water or to protect land against overflow. Embankments that have zoned construction (core and shell) are not considered. In this table, the soils are rated as a source of material for embankment fill. The ratings apply to the soil material below the surface layer to a depth of 5 or 6 feet. It is assumed that soil layers will be uniformly mixed and compacted during construction.

The ratings do not indicate the ability of the natural soil to support an embankment. Soil properties to a depth even greater than the height of the embankment can affect performance and safety of the embankment. Generally, deeper onsite investigation is needed to determine these properties.

Soil material in embankments must be resistant to seepage, piping, and erosion and have favorable compaction characteristics. Unfavorable features include less than 5 feet of suitable material and a high content of stones or boulders, organic matter, or salts or sodium. A high water table affects the amount of usable material. It also affects trafficability.

Aquifer-fed excavated ponds are pits or dugouts that extend to a ground-water aquifer or to a depth below a permanent water table. Excluded are ponds that are

fed only by surface runoff and embankment ponds that impound water 3 feet or more above the original surface. Excavated ponds are affected by depth to a permanent water table, K_{sat} of the aquifer, and quality of the water as inferred from the salinity of the soil. Depth to bedrock and the content of large stones affect the ease of excavation.

Soil Properties

Data relating to soil properties are collected during the course of the soil survey. Soil properties are ascertained by field examination of the soils and by laboratory index testing of some benchmark soils. Established standard procedures are followed. During the survey, many shallow borings are made and examined to identify and classify the soils and to delineate them on the soil maps.

Estimates of soil properties are based on field examinations and on laboratory tests of samples of similar soils in nearby areas. Tests verify field observations, verify properties that cannot be estimated accurately by field observation, and help to characterize key soils.

The estimates of soil properties are shown in tables. They include engineering index properties, physical and chemical properties, and pertinent soil and water features.

Engineering Properties

Table 21 gives the engineering classifications and the range of engineering properties for the layers of each soil in the park.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Classification of the soils is determined according to the Unified soil classification system (ASTM, 2005) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 2004).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

If laboratory data are available, the A-1, A-2, and A-7 groups are further classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, or A-7-6. As an additional refinement, the suitability of a soil as subgrade material can be indicated by a group index number.

Group index numbers range from 0 for the best subgrade material to 20 or higher for the poorest.

Rock fragments larger than 250 millimeters in diameter and 70 to 250 millimeters in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage.

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an oven-dry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field.

Liquid limit and *plasticity index* (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination.

Physical Soil Properties

Table 22 shows estimates of some physical characteristics and features that affect soil behavior. These estimates are given for the layers of each soil in the park. The estimates are based on field observations and on test data for these and similar soils.

Depth to the upper and lower boundaries of each layer is indicated.

Particle size is the effective diameter of a soil particle as measured by sedimentation, sieving, or micrometric methods. Particle sizes are expressed as classes with specific effective diameter class limits. The broad classes are sand, silt, and clay, ranging from the larger to the smaller.

Sand as a soil separate consists of mineral soil particles that are 0.05 millimeter to 2 millimeters in diameter. In this table, the estimated sand content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Silt as a soil separate consists of mineral soil particles that are 0.002 to 0.05 millimeter in diameter. In this table, the estimated silt content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Clay as a soil separate consists of mineral soil particles that are less than 0.002 millimeter in diameter. In this table, the estimated clay content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification.

The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, saturated hydraulic conductivity (K_{sat}), plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earthmoving operations.

Moist bulk density is the weight of soil (oven-dry) per unit volume. Volume is measured when the soil is at field moisture capacity, that is, the moisture content at $1/3$ - or $1/10$ -bar (33kPa or 10kPa) moisture tension. Weight is determined after the soil is dried at 105 degrees C. In the table, the estimated moist bulk density of each soil horizon is expressed in grams per cubic centimeter of soil material that is less than 2 millimeters in diameter. Bulk density data are used to compute linear extensibility, shrink-swell potential, available water capacity, total pore space, and other soil properties. The moist bulk density of a soil indicates the pore space available for water and roots. Depending on soil texture, a bulk density of more than 1.4 can restrict water

storage and root penetration. Moist bulk density is influenced by texture, kind of clay, content of organic matter, and soil structure.

Permeability (K_{sat}) refers to the ability of a soil to transmit water or air. The term "permeability," as used in soil surveys, indicates saturated hydraulic conductivity (K_{sat}). The estimates in the table indicate the rate of water movement, in inches per hour, when the soil is saturated. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Permeability is considered in the design of soil drainage systems and septic tank absorption fields.

Available water capacity refers to the quantity of water that the soil is capable of storing for use by plants. The capacity for water storage is given in inches of water per inch of soil for each soil layer. The capacity varies, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems. Available water capacity is not an estimate of the quantity of water actually available to plants at any given time.

Shrink-swell potential is the potential for volume change in a soil with a loss or gain in moisture. Volume change occurs mainly because of the interaction of clay minerals with water and varies with the amount and type of clay minerals in the soil. The size of the load on the soil and the magnitude of the change in soil moisture content influence the amount of swelling of soils in place. Laboratory measurements of swelling of undisturbed clods were made for many soils. For others, swelling was estimated on the basis of the kind and amount of clay minerals in the soil and on the basis of measurements of similar soils.

If the shrink-swell potential is rated moderate to very high, shrinking and swelling can cause damage to buildings, roads, and other structures. Special design is often needed.

Shrink-swell potential classes are based on the change in length of an unconfined clod as moisture content is increased from air-dry to field capacity. The classes are *low*, a change of less than 3 percent; *moderate*, 3 to 6 percent; *high*, 6 to 9 percent; and *very high*, greater than 9 percent.

Organic matter is the plant and animal residue in the soil at various stages of decomposition. In this table, the estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of organic matter in a soil can be maintained by returning crop residue to the soil. Organic matter has a positive effect on available water capacity, water infiltration, soil organism activity, and tilth. It is a source of nitrogen and other nutrients for crops and soil organisms.

Erosion Properties

Table 23 shows estimates of some erosion factors that affect a soil's potential for different uses. These estimates are given for each layer of every soil for K factors and are given as one rating for the entire soil for the T factor, the wind erodibility group, and the wind erodibility index. Values are reported for each soil in the park. Estimates are based on field observations and on test data for these and similar soils.

Erosion factors are shown in the table as the K factor (K_w and K_f) and the T factor. Soil erosion factors (K_w) and (K_f) quantify soil detachment by runoff and raindrop impact. These erosion factors are indexes used to predict the long-term average soil loss from sheet and rill erosion under crop systems and conservation techniques. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and K_{sat} .

Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

The procedure for determining the Kf factor is outlined in Agriculture Handbook 703, "Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)," USDA, Agricultural Research Service, 1997.

Erosion factor Kw indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments. In horizons where total rock fragments are 15 percent or more, by volume, the Kw factor is always less than the Kf factor.

Erosion factor Kf indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size. Soil horizons that do not have rock fragments are assigned equal Kw and Kf factors.

Erosion factor T is an estimate of the maximum average annual rate of soil erosion by wind and/or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.

Wind erodibility groups are made up of soils that have similar properties affecting their susceptibility to wind erosion in cultivated areas. The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible. The groups are described in the "National Soil Survey Handbook."

Wind erodibility index is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year that can be expected to be lost to wind erosion. There is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion.

Total Soil Carbon

Table 24 gives estimates of total soil carbon. Soil carbon occurs as organic and inorganic carbon.

Soil organic carbon (SOC) is carbon (C) in soil that originated from a biological source, such as plants, animals, or micro-organisms. SOC is found in both organic and mineral soil layers. The term "soil organic carbon" refers only to the carbon occurring in soil organic matter (SOM). Soil organic carbon makes up about one-half the weight of soil organic matter. The rest of SOM is mostly oxygen, nitrogen, and hydrogen.

Soil inorganic carbon (SIC) is carbon found in soil carbonates, typically as calcium carbonate layers in the soil or as clay-sized fractions throughout the soil. Carbonates in soils are most common in areas where evaporation rates exceed precipitation, as is the case in most desert environments. Typically, the carbonates accumulated from carbonatic dust or from solution during periods of wetter climates. Soil inorganic carbon also occurs in soils that formed in marl in all regions of the country.

The SOC and SIC contents are reported in kilograms per square meter to a depth of 2 meters or to a representative depth of either hard bedrock or a cemented horizon. The SOC and SIC values are on a whole soil basis, corrected for rock fragments.

SOC can be an indicator of overall soil fertility and soil quality that affects ecosystem function. SOM is the main reservoir for most plant nutrients, such as phosphorus and nitrogen. Managing for SOC by managing for SOM increases the content of these elements and improves soil resiliency.

Soil organic matter binds soil particles together and thus increases soil porosity and water infiltration and allows better root penetration and waterflow into the soil. Greater inflow of water reduces the hazard of erosion and the rate of surface water runoff.

Greater SOC levels improve not only soil quality but also the quality of air and water. Soil acts as a filter and improves water quality. Fertile soils that support plant life remove CO₂ from the atmosphere and increase oxygen levels through photosynthesis. Maintaining the level of soil organic carbon reduces C release into the atmosphere and thus can lessen the effects of global warming.

SIC influences the types of plants that will grow. High SIC levels are commonly associated with a higher soil pH, which limits the types of plants that will thrive.

Like SOM, soil carbonates, the source of SIC, also bind soil particles together. They fill voids in the soil and thus can reduce soil porosity. Compacted soil carbonates may restrict root penetration and waterflow into the soil.

Soil Features

Table 25 gives estimates of various soil features. The estimates are used in land use planning that involves engineering considerations.

A *restrictive layer* is a nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly impede the movement of water and air through the soil or that restrict roots or otherwise provide an unfavorable root environment. Examples are bedrock, cemented layers, dense layers, and frozen layers. The table indicates the hardness of the restrictive layer, which significantly affects the ease of excavation. *Depth to top* is the vertical distance from the soil surface to the upper boundary of the restrictive layer.

Potential for frost action is the likelihood of upward or lateral expansion of the soil caused by the formation of segregated ice lenses (frost heave) and the subsequent collapse of the soil and loss of strength on thawing. Frost action occurs when moisture moves into the freezing zone of the soil. Temperature, texture, density, saturated hydraulic conductivity (K_{sat}), content of organic matter, and depth to the water table are the most important factors considered in evaluating the potential for frost action. It is assumed that the soil is not insulated by vegetation or snow and is not artificially drained. Silty and highly structured, clayey soils that have a high water table in winter are the most susceptible to frost action. Well drained, very gravelly, or very sandy soils are the least susceptible. Frost heave and low soil strength during thawing cause damage to pavements and other rigid structures.

Risk of corrosion pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel or concrete. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. The rate of corrosion of concrete is based mainly on the sulfate and sodium content, texture, moisture content, and acidity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The steel or concrete in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the steel or concrete in installations that are entirely within one kind of soil or within one soil layer.

For uncoated steel, the risk of corrosion, expressed as *low*, *moderate*, or *high*, is based on soil drainage class, total acidity, electrical resistivity near field capacity, and electrical conductivity of the saturation extract.

For concrete, the risk of corrosion also is expressed as *low*, *moderate*, or *high*. It is based on soil texture, acidity, and amount of sulfates in the saturation extract.

Water Features

Table 26 gives estimates of various soil water features. The estimates are used in land use planning that involves engineering considerations.

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The four hydrologic soil groups are:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas.

The *months* in the table indicate the portion of the year in which a water table, ponding, and/or flooding is most likely to be a concern.

Water table refers to a saturated zone in the soil. Table 26 indicates, by month, depth to the top (*upper limit*) and base (*lower limit*) of the saturated zone in most years. Estimates of the upper and lower limits are based mainly on observations of the water table at selected sites and on evidence of a saturated zone, namely grayish colors or mottles (redoximorphic features) in the soil. A saturated zone that lasts for less than a month is not considered a water table.

Ponding is standing water in a closed depression. Unless a drainage system is installed, the water is removed only by percolation, transpiration, or evaporation. The table indicates *surface water depth* and the *duration* and *frequency* of ponding. Duration is expressed as *very brief* if less than 2 days, *brief* if 2 to 7 days, *long* if 7 to 30 days, and *very long* if more than 30 days. Frequency is expressed as none, rare, occasional, and frequent. *None* means that ponding is not probable; *rare* that it is unlikely but possible under unusual weather conditions (the chance of ponding is nearly 0 percent to 5 percent in any year); *occasional* that it occurs, on the average, once or less in 2 years (the chance of ponding is 5 to 50 percent in any year); and *frequent* that it occurs, on the average, more than once in 2 years (the chance of ponding is more than 50 percent in any year).

Flooding is the temporary inundation of an area caused by overflowing streams, by runoff from adjacent slopes, or by tides. Water standing for short periods after rainfall or snowmelt is not considered flooding, and water standing in swamps and marshes is considered ponding rather than flooding.

Duration and *frequency* are estimated. Duration is expressed as *extremely brief* if 0.1 hour to 4 hours, *very brief* if 4 hours to 2 days, *brief* if 2 to 7 days, *long* if 7 to 30 days, and *very long* if more than 30 days. Frequency is expressed as none, very rare, rare, occasional, frequent, and very frequent. *None* means that flooding is not probable; *very rare* that it is very unlikely but possible under extremely unusual weather conditions (the chance of flooding is less than 1 percent in any year); *rare* that it is unlikely but possible under unusual weather conditions (the chance of flooding is 1 to 5 percent in any year); *occasional* that it occurs infrequently under normal weather conditions (the chance of flooding is 5 to 50 percent in any year); *frequent* that it is likely to occur often under normal weather conditions (the chance of flooding is more than 50 percent in any year but is less than 50 percent in all months in any year); and *very frequent* that it is likely to occur very often under normal weather conditions (the chance of flooding is more than 50 percent in all months of any year).

The information is based on evidence in the soil profile, namely thin strata of gravel, sand, silt, or clay deposited by floodwater; irregular decrease in organic matter content with increasing depth; and little or no horizon development.

Also considered are local information about the extent and levels of flooding and the relation of each soil on the landscape to historic floods. Information on the extent of flooding based on soil data is less specific than that provided by detailed engineering surveys that delineate flood-prone areas at specific flood frequency levels.

Chemical Soil Properties

Table 27 shows estimates of some chemical characteristics and features that affect soil behavior. These estimates are given for the layers of each soil in the park. The estimates are based on field observations and on test data for these and similar soils.

Depth to the upper and lower boundaries of each layer is indicated.

Cation-exchange capacity is the total amount of extractable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. Soils having a low cation-exchange capacity hold fewer cations and may require more frequent applications of fertilizer than soils having a high cation-exchange capacity. The ability to retain cations reduces the hazard of ground-water pollution.

Soil reaction is a measure of acidity or alkalinity. The pH of each soil horizon is based on many field tests. For many soils, values have been verified by laboratory analyses. Soil reaction is important in selecting crops and other plants, in evaluating soil amendments for fertility and stabilization, and in determining the risk of corrosion.

Calcium carbonate equivalent is the percent of carbonates, by weight, in the fraction of the soil less than 2 millimeters in size. The availability of plant nutrients is influenced by the amount of carbonates in the soil. Incorporating nitrogen fertilizer into calcareous soils helps to prevent nitrite accumulation and ammonium-N volatilization.

Gypsum is expressed as a percent, by weight, of hydrated calcium sulfates in the fraction of the soil less than 20 millimeters in size. Gypsum is partially soluble in water. Soils that have a high content of gypsum may collapse if the gypsum is removed by percolating water.

Salinity is a measure of soluble salts in the soil at saturation. It is expressed as the electrical conductivity of the saturation extract, in millimhos per centimeter at 25 degrees C. Estimates are based on field and laboratory measurements at representative sites of nonirrigated soils. The salinity of irrigated soils is affected by the quality of the irrigation water and by the frequency of water application. Hence, the salinity of soils in individual fields can differ greatly from the value given in the table. Salinity affects the suitability of a soil for crop production, the stability of soil if used as construction material, and the potential of the soil to corrode metal and concrete.

Sodium adsorption ratio (SAR) is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity (K_{sat}) and aeration, and a general degradation of soil structure.

Formation and Classification of the Soils

This section relates the soils in Sunset Crater Volcano National Monument to the major factors of soil formation and describes the system of soil classification.

The soils of Sunset Crater Volcano National Monument (Sunset Crater Volcano NM) are dominated by fragments of welded pyroclastic grains and, for the most part, do not have the weathered mineral grains found in most soils. The welded pyroclastic grains consist of nonmineral glass, mineral feldspar, pyroxenes, olivine, and other exotic minerals associated with volcanoes. These substantially different grains have substantially different characteristics and qualities. Understanding volcanic processes as well as soil-forming processes helps in understanding how different the soils in the park can be.

Factors of Soil Formation

Soils form a special covering of the earth's surface that provides a place for minerals, water, organic matter, and air to mingle. Mineral grains in combination with air and water provide an environment for plants, animals, and micro-organisms. Soils are products of various natural and/or human-influenced processes. Soils can vary with chemical composition, mineral structure, granular surface charges, compaction, soil structure, and more, all of which affect soil character and soil qualities (such as water infiltration rates, erodibility, and available water-holding capacity). Soils differ in their appearance, productivity, and management requirements due to fundamental complex chemical and physical properties. The characteristics and properties of soils are determined by physical and chemical processes that result from the interaction of five soil-forming factors. These factors of soil formation are interdependent, and few generalizations can be made regarding any one factor unless the effects of the other factors are known. The term "pedogenesis" is often used to connote the processes of soil formation.

The soil-forming factors are parent material, climate, organisms, time, and relief or topography. *Parent material* is the source material in which soils formed. Soils are influenced by the texture and structure of the parent material and its mineralogical and chemical composition. *Climate* is predominantly the temperature and kind and amount of precipitation. Climate is also the seasonal distribution of temperature and precipitation. *Organisms* are the plants and other organisms living in and on the soil, including humans. *Time* refers to how long the soil-forming factors have been operating on a particular landscape. *Relief* or *topography* is the shape and elevation of the landscape. It affects internal and external soil properties, such as soil drainage, aeration, susceptibility to erosion, and the soil's exposure to the sun and wind (Jenny, 1941).

The influence of each soil-forming factor varies. Soils may differ significantly from place to place in a survey area or soils may differ within very short distances as a result of complex interactions among the five factors. Conversely, survey areas may have consistent stretches of one type of soil where soil-forming factors are uniform. The soil-forming factors in relationship to the soils of Sunset Crater Volcano National Monument are discussed in the following paragraphs.



Figure 83.—The numerous peaks of the San Francisco Mountain, a stratovolcano that erupted 400,000 years ago. This mountain sits to the west in the backdrop of Sunset Crater Volcano National Monument. Map unit 21 (Cinderhill-Kana'a complex, 3 to 15 percent slopes) lies in the foreground. A late fall storm may not be cold enough for snow to cover the park at elevations of 6,800 to 8,039 feet (the top of Sunset Crater) but will coat Humphrey's Peak (obscured in clouds to the right), the top of the San Francisco Mountain at an elevation of 12,633 feet. The visible peak in the center is Agassiz Peak (elevation of 12,356 feet). Fremont Peak (elevation of 11,969 feet) is on the far left. Doyle Peak (elevation of 11,460 feet) sits in front of Fremont Peak.

Parent Material

Parent material refers to the source material (whether mineral or organic) from which soils form. In Sunset Crater Volcano NM, the vast majority of parent materials originate from volcanic processes. The dominant volcanic processes in the park are mild eruptions which cause lava flows and explosive sequences which create cinder cones from the fallout of tephra. A third important parent material is the accumulated organic material in lava flows. In addition, one small area in and around Bonito Park near the park entrance has another kind of parent material—playa deposits.

Volcanic Processes

Sunset Crater Volcano is a small part of the San Francisco Volcanic Field. Like many volcanic fields, the San Francisco Volcanic Field sits over a hot spot in the mantle. Evidence of many previous episodes of volcanism occurs in a path upon the crust of the earth, which has shifted in relation to the mantle over time. Various types of volcanoes occur within the volcanic field, including a stratovolcano, dome volcanoes, shield vents, and cinder cones. Many of these occur in or near the park. San Francisco Mountain to the west is a stratovolcano (fig. 83). O'Leary Peak to the north is a lava dome (Duffield, 1997).

The principal events that shaped the land within Sunset Crater Volcano National Monument are cinder cone eruptions and lava flows. Magma-transport pipelines,

referred to as vents, serve to release pressure in the earth's mantle into the atmosphere. When magma is thrown violently into the air, the result is a cinder cone, a landform created from a spattering of magma into a ring around the vent of a pipe. A cone shape on the surface is produced as the volcano sprays cooling, liquid rock aggregates that turn solid while in the air. Sunset Crater Volcano NM contains two named cinder cones (Sunset Crater and Lenox Crater) and one unnamed cone. The solidified aggregates are called tephra, which can be further classified as volcanic bombs, cinders, or ash, depending on size. Magma extruding from tubes without being thrown to the air becomes lava flows (fig. 84).

Volcanic eruptions at Sunset Crater are thought to have begun in 1064 A.D. (Smiley, 1958). Eruptions continued to about 1200 A.D., covering much of the park with cinders to depths ranging from 10 to 40 feet. Sunset Crater, the cinder cone itself, rose to 1,000 feet during this time. Cinders from Sunset Crater have been found in measurable depths from 6 to 12 miles away (Hooten et al., 2001). Volcanic eruptions also occurred at Lenox Crater. Lenox Crater is thought to be more than 100,000 years in age, older than several cinder cones of the volcanic field.

Other notable volcanic forms exist on the park landscape. Cinder lands are relatively flat areas lacking vegetation where fallen cinders have buried the pre-existing landscape some distance from the cone. Spatter cones, or hornitos, form where lava is forced up through an opening in the cooled surface of a lava flow (Fischer, 2007). During the eruption, pieces of the Sunset Crater cone breached and rafted from the cone with flowing lava (fig. 85). These agglutinate mounds, although buried to some extent under cinders, are still visible as red (from oxidation) mounds above the expanse of black cinders (Holm, 1987). Sunset Crater reformed as a cone. In one



Figure 84.—The Bonito Lava Flow extends west and north of Sunset Crater within Sunset Crater Volcano National Monument. San Francisco Mountain is in the background. The lava flow is mapped as Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes (map unit 27).



Figure 85.—Agglutinate mounds are parts of earlier cinder cones that have rafted away from the original site. Agglutinate mounds and other landforms of a lava field are mapped as Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes (map unit 28).

final eruptive episode, the cone was crowned with oxidized iron and sulfur, which left a tiara of yellow and red (fig. 86). This gave the impression of a sunset, the basis for the name of the cinder cone and the park.

Tephra Deposits

The tephra fallout process starts when molten magma is ejected from the mantle of earth into the sky and then falls to the ground, where it forms a cinder cone. Molten magma is essentially rock in liquid form. Magma cools quickly in the atmosphere. Fast, sudden cooling favors the formation of glass without mineral bonds over crystals. As rock solidifies in the air, gases escape the cooling magma quickly. Forms of bubbling, roughly spherical, mass fragments have large pore spaces.

Tephra is both unusual and significant as soil parent material because the common rock fragments are porous. The pore spaces give the tephra fragments significantly different moisture retention characteristics. These spaces are not interconnected and do not allow water to infiltrate through soil unimpeded. Pore spaces collect and retain the moisture needed to initially germinate seeds and to provide habitat for small animals.

Initially, the tephra falls from the sky into piles. The fragment size and the shapes of the scattering are determined by the varying power behind the eruption, the mass of the fragment, and the varying force of the wind. The distance the tephra travels from the source depends partly on aggregate size. Volcanic bombs are large fragments that land most frequently near the vent. Cinders are gravel that may travel further but are still influenced greatly by gravity (fig. 87). Ash particles are the small fragments easily

carried a great distance by wind. “Cinders” has been used in the past to informally describe the concept of tephra. The formal classifications of tephra, however, are based on size. In this publication, cinders refer only to tephra gravel. The size of tephra fragments greatly affects soil formation in the park.

Four new soil series were identified in Sunset Crater Volcano NM. These soils vary with respect to the size and distribution of tephra fragments. The distribution of fragment sizes fits patterns of tephra fallout with respect to the initial fallout and later redistribution of ash and dust by wind and rain. The four new soil series are Kana`a, Cinderhill, Blackash, and Sunsetcrater. These soils all formed from the same volcanic parent material resulting from cinder cone eruption but have different physical soil properties and ecological sites (see table 8).

Kana`a, Cinderhill, Blackash, and Sunsetcrater soils are all classified in a Vitrandic subgroup (see table 28). Vitrandic soils, according to Soil Taxonomy, require more than 35 percent rock fragments, of which 66 percent must be cinders. Vitrandic soils also require more than 5 percent volcanic glass in their profile. Laboratory data for Sunsetcrater soils support the Vitrandic soil subgroup classification (see table 30). In looking at table 28, all four new series appear similar based on the Vitrandic classification, but they are in fact different. Along with soil subgroup and great group classification, soils are identified by family particle-size class. Family particle-size class characterizes the grain-size composition of the whole soil, including both the fine earth (sand, silt, and clay) and rock fragments (cinders, gravel, and volcanic bombs). The differences between the family particle-size class of Kana`a, Cinderhill, Blackash, and Sunsetcrater soils are related to eruption velocity and landform position. (See [Sunset Crater Volcano National Monument 3D Soil Types](#) included with this report.)



Figure 86.—The top of Sunset Crater has cinders coated in oxidized iron and sulfur, which provide its colors. This area is mapped as Kana`a-Cinder land complex, 15 to 60 percent slopes (map unit 26).

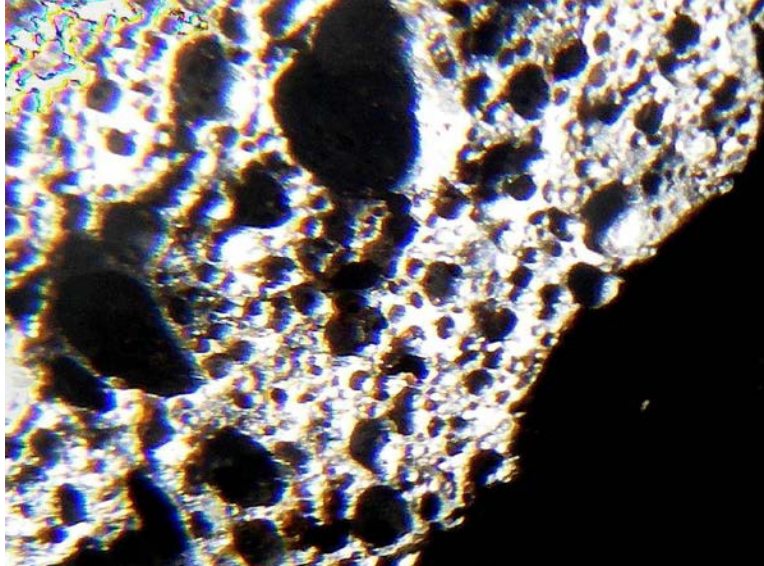


Figure 87.—A microphotograph of a cinder fragment from Sunset Crater. Cinder fragments originated from liquid rock that once held gases trapped within the pyroclast. The Sunset Crater explosions caused the magma (or liquid rock) to be ejected quickly through the vent and into the atmosphere. As the liquid rock traveled through the air, it cooled quickly around the bubbling gases that were escaping the cooling rock fragments. Cavities, or pore spaces, were left in the cooled fragment. These spaces allow moisture or air to linger for a long time, thus providing conditions where life can flourish.

Kana`a soils classify as cindery for family particle-size class. A cindery particle-size class requires more than 60 percent cinders or volcanic ash throughout the profile. Kana`a soils are on the summits of cinder cones, such as Sunset Crater, and have the highest percentage of cinder-sized fragments compared to other soils in the park and larger volcanic bombs. Because of the higher percentage of large cinders, Kana`a soils are less stable for climbing. This is one reason the Sunset Crater summit trail was closed. Kana`a soils frequently occur in association with areas of Cinder land in the park. The miscellaneous area Cinder land lacks vegetation and fine grains. In general, because Kana`a soils are deposits of the largest fragments, they typically occur in areas near the vent of the associated cinder cone. (See [Sunset Crater Volcano National Monument 3D Soil Types](#) included with this report.)

Cinderhill soils classify as ashy-skeletal for family particle-size class. An ashy-skeletal particle-size class requires more than 35 percent cinders and volcanic glass in the soil profile. Cinderhill soils contain 35 to 75 percent cinders in their profile. These soils formed from lighter cinder fragments that were ejected during the eruption and deposited on the backslope of the cinder cone. The remaining soil particles in Cinderhill soils are sand-sized fragments. These finer sand-sized fragments act more like a true soil and therefore support more vegetation than the neighboring Kana`a soils uphill. Some of the Cinderhill soils were breached, rafted down off the Sunset Crater cone by flowing lava, and deposited downhill adjacent to the Bonito Lava Flow. The agglutinate mounds can be seen as red features capping the top of the lava flow at the base of Sunset Crater.

Sunsetcrater soils also classify as ashy-skeletal for family particle-size class. Like Cinderhill soils, they occur on backslopes. Sunsetcrater soils have a layer of brown weathered cinders beneath the fresh Sunset Crater tephra covering. The weathered cinders were deposited on the sides and around the base of Lenox

Crater from a prior volcanic event (fig. 88). The brown cinders were then covered by the black cinders of the Sunset Crater eruption. The covered brown cinders have been weathering and developing clay-sized non-crystalline materials as well as soil structure and horizonation. Because the developing soil structure holds more available water for plants, Sunsetcrater soils have slightly more vegetative growth than the similar Cinderhill soils. Because of this clay movement and structure development, Sunsetcrater soils have different soil order and great group classifications than Cinderhill soils (see table 29).

Blackash soils classify as ashy for family particle-size class. An ashy particle-size class requires less than 35 percent cinders in the soil profile and the presence of volcanic glass. The parent material particles of Blackash soils traveled the farthest from the source during the eruption. These particles were deposited on the footslopes and toeslopes of cinder cones. These small particles were also more susceptible to subsequent movement by wind and rains. Blackash soils commonly occur in the margins of the Bonito Lava Flow, near agglutinate mounds and other features of the lava field. These soils have the most sand-sized particles and therefore support the most vegetation of all four newly named soils. (See [Sunset Crater Volcano National Monument 3D Soil Types](#) included with this report.)

Cumulization of Dust and Ash Particles

Ash, the smallest of the ejected tephra particles, can easily be transported great distances from the vent by wind and small amounts of water. Ash is carried by winds along with other particulates, such as carbonate dust, and deposited on top of larger



Figure 88.—Lenox Crater (in the background) as seen from Bonito Park during summer bloom following monsoonal rains. Bonito Park is the playa seen to the south near the park's west entrance. The playa is in map unit 23 (Cumulic Haplustolls extremely gravelly loamy sand, 0 to 2 percent slopes). Map unit 30 (Sunsetcrater extremely gravelly loamy sand, 15 to 30 percent slopes) occurs on forested Lenox Crater.

cinders. Over time these wind-transported ash particles settle into the soil profile between the cinders and become pushed down through the soil profile by precipitation or by freeze-thaw processes. The smallest particles of ash, the fine ash, may settle for a time and then be retransported by even modest winds, especially when grain surfaces lack the cohesion provided by moisture. Ash drifts into dunes or is blown into canyons (Colton, 1932). Much of the coarse ash from the eruption is found in nearby Wupatki National Monument.

Ash particles tend to collect a few centimeters beneath the surface, slowing infiltration rates at that depth (see subsurface K_f values in table 23). This early soil formation process, which is apparent at Sunset Crater Volcano National Monument, is called cumulization (fig. 89). Cumulization includes eolian, hydrologic, or human-induced addition of mineral particles to the surface of a soil, typically at the base of a slope or on a flood plain. Slow, gradual additions into the soil are implied as the surface aggrades and the profile thickens (Riecken and Poetsch, 1960; Schaetzl and Anderson, 2005).

In the soils of Sunset Crater Volcano NM, additions to the soil surface occur more frequently through cumulization than through accumulation in surface heaps (as in arid climates dominated by dry winds or in alluvial landscapes with flood deposits). Fine matter moves down into the profile both between and inside pore spaces within cinders. These fine ash particles move relatively quickly below the surface due to the abundant quantity of available pore spaces. This quick incorporation of ash particles prevents any accumulation on the surface that would create heaps.

With time, cumulization of fine particles below the surface causes infiltration to slow to the point where water ceases to push fine grains deeper into the profile. As infiltration slows, more ash particles collect in the area of concentration. The area of ash concentration and slower infiltration rates provides more available water for vegetation and seed germination. This incorporation of particles also influences habitat for vegetation in the barren lava flows. Organic matter transported with the ash particles accumulates on the surface, within rock pores, and between cracks of the lava flow, thus acquiring further insulation from heat and desiccation and providing nutrients for seedlings (see table 24). The pH is also held in a neutral state, which encourages phosphorous solubility (see table 27). Because water is held in these areas, life flourishes. Plants also help to form water-holding areas by forming mats of roots along the bottom of the cumulized horizon.

Blackash soils have the greatest amount of cumulization of ash-sized particles. These soils are located the farthest from the vent and are on footslopes or toeslopes downhill from the cinder cone, in areas with small particles deposited by wind and slope alluvium. (See [Sunset Crater Volcano National Monument 3D Soil Types](#) included with this report.) The effects of cumulization are increasingly evident near the base of hillslopes, where material that eroded from soils upslope has accumulated (Buol et al., 2011). This is evident in map unit 20 (Cinderhill-Blackash complex, 15 to 60 percent slopes) and map unit 28 (Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes). Cumulization is also evident in Cinderhill soils to a lesser extent in map unit 21 (Cinderhill-Kana'a complex, 3 to 15 percent slopes) and map unit 22 (Cinderhills-Lava flows complex, 2 to 15 percent slopes).

The two map units of Sunsetcrater soils—map unit 29 (Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes) and map unit 30 (Sunsetcrater extremely gravelly loamy sand, 15 to 35 percent slopes)—also show some degree of cumulization. In this survey, apparent changes in the soil profiles due to cumulization are assumed to be geological. Affected soils are mapped as Entisols.

Lava Flows

A second parent material at Sunset Crater Volcano NM that has not yet weathered to soil is the basaltic lava flows. These lava flows are cemented and will require

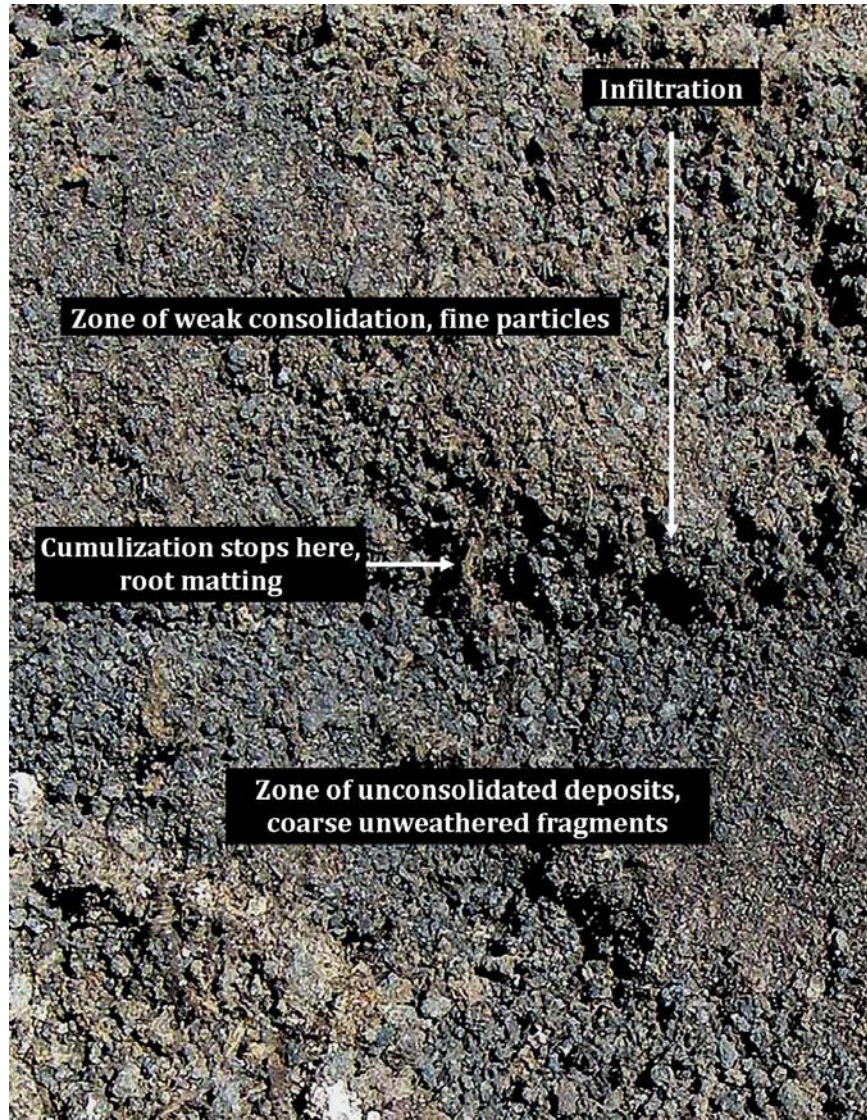


Figure 89.—A soil profile showing cumulization. Cumulization is the accumulation of fine grains on the surface, due to wind or water, which simultaneously penetrate the upper portion of a profile with precipitation events. Cumulization is apparent in most soils of Sunset Crater Volcano National Monument. Its extent depends on landscape position.

perhaps tens of thousands of years, depending on climate and organisms, to weather into soil. Extensive lava flows originated from the base of Sunset Crater during eruptive episodes. One flow within the park created the Bonito Lava Flow. A second flow outside the park, in the area along the road to Wupatki National Monument, created the Kana'a Lava Flow.

A number and variety of plants can be seen growing amid the extensive lava flows because favorable conditions for plants still exist between cracks along zones of weaknesses. The plants help to weather the basaltic groundmass to clays as well as to sand (wherever fine grains of quartz are found). The cracks within lava flows have a special biome. This is described in further detail in the following paragraphs on organic material.



Figure 90.—Soil surface in an area of map unit 27 (Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes). Organic matter has accumulated within crevices of lava flows with particles of sand and carbonate silt. Organic matter has many beneficial effects for soils, including improved moisture distribution and retention, nutrient availability, and aeration.

Organic Material

Plants grow within the cracks along zones of weakness in lava flows (fig. 90). Organic matter accumulates by eolian processes and cumulation and becomes permanently trapped. Water finds its way into the cracks as well. With minerals, organic material, water, and air, plants have everything they need for germination and growth (fig. 91). Organic soils form in place from the accumulation and decomposition of plant material, such as wood, leaves, and tree bark. Organic matter may encourage the growth of beneficial micro-organisms and sustain their presence in decomposing humus. Other dusts and debris, such as small silica grains of very fine sand or fine carbonate silt, may also blow in regionally.

Organic soils in the survey area occur mixed within `a`a lava of the Bonito Lava Flow. The Lithic Haplofibrists in map unit 27 are unique areas with vegetative cover among bare lava flow. Such organic soils occur in other arid climates, such as in Hawaii and Idaho, on top of lava flows. A study at Craters of the Moon National Monument in Idaho found that organic soil acidity is directly influenced by the vegetation type (Vaughn and McDaniel, 2009). The organic soils are the initial soils occurring on lava flows and hence represent the primary stage of succession. The level of acidity may be related to the types of plants that have grown on the lava in the past. Successions of plants occur as the lava continues to weather, promoting populations of wildlife and vegetation.

Organic matter has many benefits:

- 1) It is a source of 90 to 95 percent of the nitrogen in unfertilized soils.
- 2) It can be the major source of both available phosphorous and available sulfur where it occurs as humus in appreciable amounts.
- 3) It supports, directly or indirectly, the cation-exchange capacity, commonly providing 30 to 70 percent of the total amount.
- 4) It commonly increases water content at field capacity, increases available water content in sandy soils, and increases rates of air and water flow.

5) It acts as a chelate. Soluble chelates help mobilize micronutrient metal ions. This increases the availability of these ions to plants and their mobility in soils.

6) It is a supply of carbon for many beneficial microbes.

7) In the form of humus, it buffers soil against rapid changes in acidity, alkalinity, and salinity (Miller and Gardiner, 1998).

The major portion of the Bonito Lava Flow is mapped as Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes (map unit 27). Other parts of the lava flow are in Cinderhill-Lava flows complex, 2 to 15 percent slopes (map unit 22) and Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes (map unit 28).

Playa Deposits

Twenty-six acres of Bonito Park in the survey area have playa deposits. These deposits accumulate slowly. Cumulization in these deposits occurs not as incorporation, as seen in tephra, but in the more common manner of heaping. Alternating lenses of finer or coarser material are deposited through alluvial processes and flooding events. Deeper parts of relict lakes are characterized by the presence of fine silt and clay. The playa is represented by map unit 23 (Cumulic Haplustolls extremely gravelly sandy loam, 0 to 2 percent slopes).

Organisms

By Jennifer M. Puttere, ecological site inventory specialist, Natural Resources Conservation Service.

Biotic factors include living organisms that are both on the soil surface (e.g., plants and animals) and under the soil surface (e.g., nematodes, springtails, soil bacteria, and soil fungus). Many different interrelated events combine to develop and alter the



Figure 91.—A wax currant grows in organic soil in a crevice on `a`a lava in an area of map unit 27 (Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes).

Soil Survey of Sunset Crater Volcano National Monument, Arizona

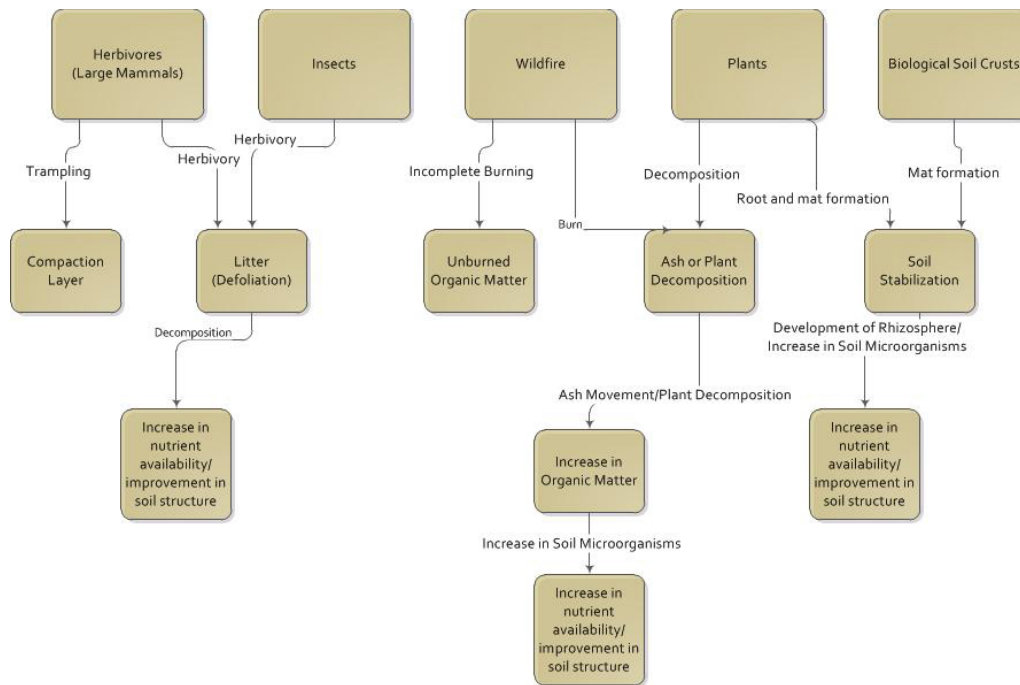


Figure 92.—A flow chart summarizing interrelationships of biotic processes.

surface soil (fig. 92). Large herbivores walk on the surface, compacting the soil and selectively browsing plants (fig. 93). Insects, such as grasshoppers, defoliate and create litter; plants grow roots and anchor the soil; wildfire creates nutrient-rich ash; and soil microbes thrive within the areas created by roots penetrating the rhizosphere.

Large mammals can reduce nutrient cycling by uprooting and trampling plants. They also can contribute to the compaction of soils, which slows down the cycling processes (Belovsky and Slade, 2000). Large herbivorous mammals can affect the mineralization rate by selectively browsing more palatable plants and leaving less palatable and less decomposable plants (McNaughton et al., 1997). Insects can also affect soil nutrients by feeding on plants that are more easily decomposed (Belovsky and Slade, 2000).

Vascular plants stabilize the soil surface, distribute nutrients, and contribute organic matter to the soil. Plants also influence soil properties, such as soil structure. Plants can promote soil aggregation in various ways, such as by root penetration, modifying the soil water regime, creating networks of roots in the soil profile, increasing microbial activity in the rhizosphere, and increasing soil carbon input through roots and litter (Angers and Caron, 1998). Soil microbial communities are the primary drivers of nutrient cycling in the rhizosphere (Williams et al., 2012). Microbial activity directly influences plant productivity and diversity by influencing plant growth and development, plant competition, and nutrient and water intake (Kennedy and Stubbs, 2006).

Biological soil crusts are relationships between differing proportions of soil particles, cyanobacteria, algae, microfungi, lichens, and bryophytes. They include cryptobiotic, cryptogamic, and microbiotic soil crusts (Rosentreter et al., 2007). Biological soil crusts reduce the hazard of soil erosion, contribute organic carbon to the soil, fix nitrogen, and either promote the growth of vascular plant seedlings or adversely affect them (Bhatnagar and Bhatnagar, 2005). One of the dominant sources of nitrogen in desert ecosystems is cyanobacteria and cyanolichens. In regions where rainfall is low, the ability of these organisms to fix nitrogen and make it available for plant use is crucial (Belnap, 2002).

Wildfire affects soil and plant nutrient cycling by converting all or part of the organic matter and detritus into organic ash and other combustion products (fig. 94) (Boerner, 1982). Other nutrients may be lost to the atmosphere or remain incompletely burned (Boerner, 1982). Frequent fires may damage a site's soil fertility and alter nutrient cycling (Williams et al., 2012).

Climate

In Sunset Crater Volcano NM, summers are moderately cool and have a monsoonal rain pattern that starts in July and ends in late September. In fall, monsoonal patterns transition to sunnier days and colder nights. In winter, temperatures are cold, deep accumulations of snow are common, and cold winds occur occasionally. Spring brings moisture and moderately warmer, stronger winds. In June, temperatures become substantially warmer and drier. The climate of the park tends to be consistent with the Mogollon Rim climates. It is categorized as the warm summer subtype of a humid continental climate, or Dsb in the Köppen climate classification system. See tables 1, 2, and 3 (which are discussed in the introduction) for more information on climate in the park.

Climate affects soil moisture content and soil temperature, thus affecting the kind and number of soil organisms. Infiltration of moisture after rainfall affects soluble and insoluble transport within and out of the soil profile. Soil horizon development is dependent on climatic factors.

Winds are predominantly from the southwest during much of the year. These winds are responsible for carrying organic matter, carbonate dust, and small grains of sands



Figure 93.—Tracks across Cinderhill soil in an area of Cinderhill-Kana`a complex, 3 to 15 percent slopes (map unit 21). Animals and people tracks crisscross the tephra surface. These tracks will disappear with next winter's snowfall.



Figure 94.—Climate, lightning strikes, and wildfires visibly impact organisms as well as soils. Wildfires contribute to plant and animal decomposition as well as mineral weathering. This area is mapped as Cinderhill-Blackash complex, 15 to 60 percent slopes (map unit 20).

into the park and depositing them in lava flow crevices and atop masses of tephra. These materials can be redistributed by subsequent rains. The climate of the park is highly variable over both spatial distances and time.

Topography

Topography is characterized by the length, shape, aspect, and degree of surface slope (figs. 95 and 96). Topography, or physical relief, influences soil formation through moisture distribution and runoff. The amount of water entering the soil depends on slope, soil permeability, and the intensity of rainfall. Soil development is inhibited in steeply sloping areas where runoff rates increase and infiltration rates decrease.

Soils on south aspects receive more direct sunlight and are drier and hotter than soils on north aspects. These conditions influence soil formation as well as kind of vegetation, susceptibility to erosion, and cycles of freezing and thawing. Aspect may also influence the amount of cumulation in a profile. Finer grains are removed on the northeast aspect of slopes as the dominant wind forces are typically from the southwest.

The influence of topography on cumulation is evident in the collection of ash grains below the surface near the base of cones and anywhere slope decreases. The relationship between the degree of cumulation and topographic position is shown in the [Sunset Crater Volcano National Monument 3D Soil Types](#) figure. Blackash soils have the greatest degree of cumulation. These soils, which have an ashy

particle-size class, occur downslope in slope breaks, at the bottom of swales, and in depressional areas. Cinderhill soils, which have an ashy-skeletal particle-size class, have an intermediate degree of ash cumulation and occur in gently to moderately sloping areas above Blackash soils. Kana'a soils lack cumulation and occur in places that are protected from the collapse of winds. These soils commonly occur on the shoulders and summits of hills. Sunsetcrater soils are a case where variable deposition and development has occurred in a short amount of time. Variable rates and extent of deposition can contribute to dramatic regional variation in a soil-stratigraphic unit. When specific pedologic thresholds are exceeded, soils develop very quickly (McDonald and Busacca, 1990).

Topography also has a visible influence on the accumulation of organic matter and growth of plants in lava flows. Due to the rugged nature of 'a'a lava, soil material that may occur at the surface depends on the forces of gravity and meteoric rainfall. Substantial periods of time are required for organic material to accumulate enough to support vegetation (Vaughn and McDaniel, 2009). Lava flows tend to fill in low-lying areas since viscous liquid rock travels slowly across the ground during lava eruptions (fig. 97). Lava may also travel underground long distances through tubes and exit the tubes in low-lying areas. Although the surface of slow-moving 'a'a lava in much of the Bonito Lava Flow is extremely rough, plants, including Apache plume, ponderosa pine, and wax currant, still grow (fig. 98).



Figure 95.—The common topographic relationship between Cinderhill and Blackash soils. Blackash soils have the highest degree of cumulation of ash grains and other fine grained material. These soils occur typically downslope in slope breaks and in depressional areas. Cinderhill soils have a moderate degree of ash cumulation and are typically in gently to moderately sloping areas above Blackash soils. The red peak in the background is an agglutinate mound. This area is mapped as Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes (map unit 28) and Cinderhill-Lava flows complex, 2 to 15 percent slopes (map unit 22).

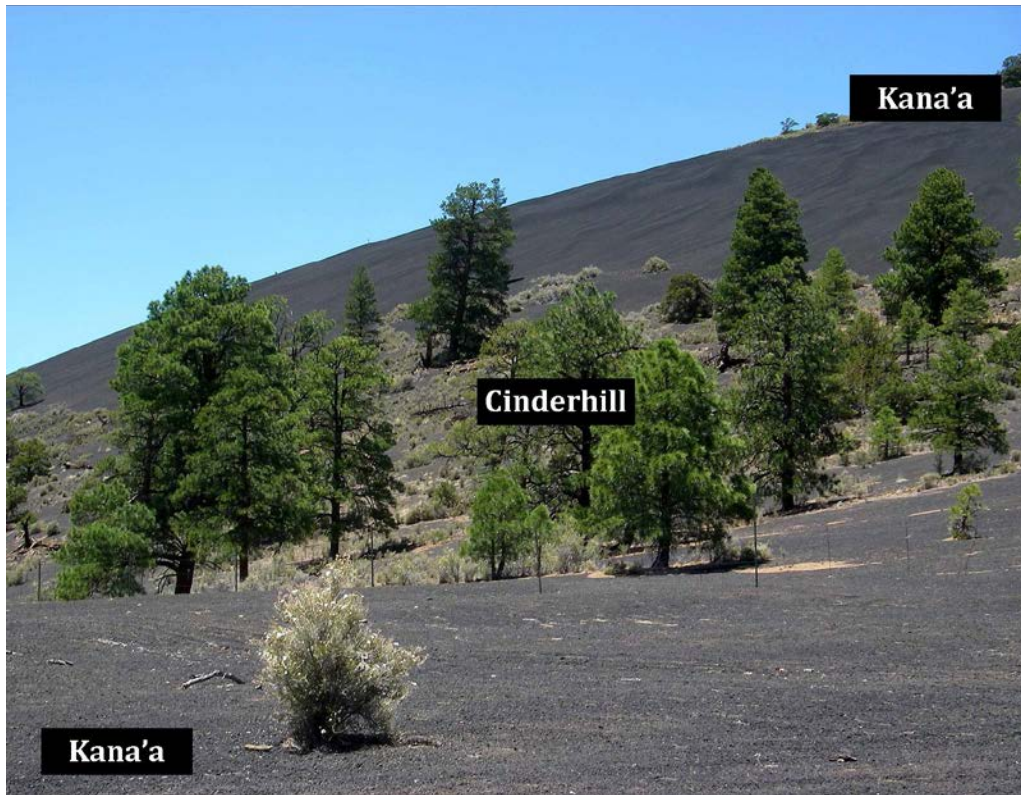


Figure 96.—The common relationship between Cinderhill and Kana`a soils. Cinderhill soils are commonly on gentle or moderately gentle slopes that may collect some ash grains. Kana`a soils are commonly on summits or in areas away from slopes, where there may be protection from the collapse of winds. Cinderhill soils have a moderate degree of cumulization, whereas Kana`a soils lack cumulization. This area is mapped as map unit 24—Kana`a extremely gravelly sand, 1 to 3 percent slopes (foreground labeled “Kana`a”), as map unit 20—Cinderhill-Blackash complex, 15 to 60 percent slopes (area labeled “Cinderhill”), and as map unit 26—Kana`a-Cinderland complex, 15 to 60 percent slopes (map unit 26).

Time

Time for parent material, climate, organisms, and topography to interact with the soil is also a soil-forming factor (fig. 99). In Sunset Crater Volcano NM, soil development or weathering is slight because the tephra has been in place less than a thousand years, with the exception of the Sunsetsrater series. The importance of time is evident when the Sunset Crater area is considered within the context of the much older and more developed San Francisco Volcanic Field. The San Francisco Volcanic Field has older, more stable landforms that have weathered over time to create developed soils. For example, the San Francisco Peaks, which can be seen from almost anywhere within a distance of 50 miles, have developed soils with zones of calcium carbonate, clay, and organic matter accumulations.

In Sunsetsrater soils, the cinders from Sunset Crater overlie the cinders from an earlier eruption (fig. 100). The older buried cinders have developed coats of oxidized iron rust. This oxidation has changed the character and quality of the soil. Oxidation may have reduced the size of the pores within the cinders. It also started to create soil structure and increase the water-holding capacity. Due to this weathering over time, Sunsetsrater soils are the most developed soils in the park.

In the future, much of Sunset Crater will likely be further buried by lava and tephra from eruptions within the volcanic field. Where further burial does not occur,

the lava and tephra may eventually weather into soil. At present, an association of nonmineral volcanic glass along with mineral feldspars, pyroxenes, and olivine makes up pyroclastic grains. All of these components, with the exception of feldspar, cannot resist weathering on a scale of hundreds of thousands of years. In addition, there may be thousands of years of mineral alterations through the processes of chemical weathering, physical weathering, and geologic metamorphism, in conjunction with transport mechanisms, such as sedimentation and soluble transport. These processes over time will weather the pyroclastic grains into soil.

Classification of the Soils

Soils are named and classified on the basis of physical and chemical properties in their horizons (layers). Color, texture, structure, and other properties of the soil to a depth of 2 meters are used to key the soil into a classification system. This system helps people to use soil information and also provides a common language for scientists.

Soils and their horizons differ from one another, depending on how and when they formed. Soil scientists use the five soil-forming factors to help predict where different soils may occur. The degree and expression of the soil horizons reflect the extent of



Figure 97.—View of the Bonito Lava Flow from the south rim of Sunset Crater. Lava flows tend to fill in low-lying areas and even out topographies over a wide area. An area of Cinderhill-Blackash complex, 15 to 60 percent slopes (map unit 20) is in the foreground. The lava flow is mapped as Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes (map unit 28) and Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes (map unit 27). Beyond the lava flow is an area of Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes (map unit 29). The ridge beyond the lava flow is outside the park, in Coconino National Forest. The landform directly across the lava flow is another older cinder cone, consisting of Robinson Mountain and Robinson Crater.



Figure 98.—An area of Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes (map unit 27). Locally, `a`a lava forms a rough surface that is hazardous to cross. Some small brush, such as Apache plume, grows in the crevices of `a`a lava.

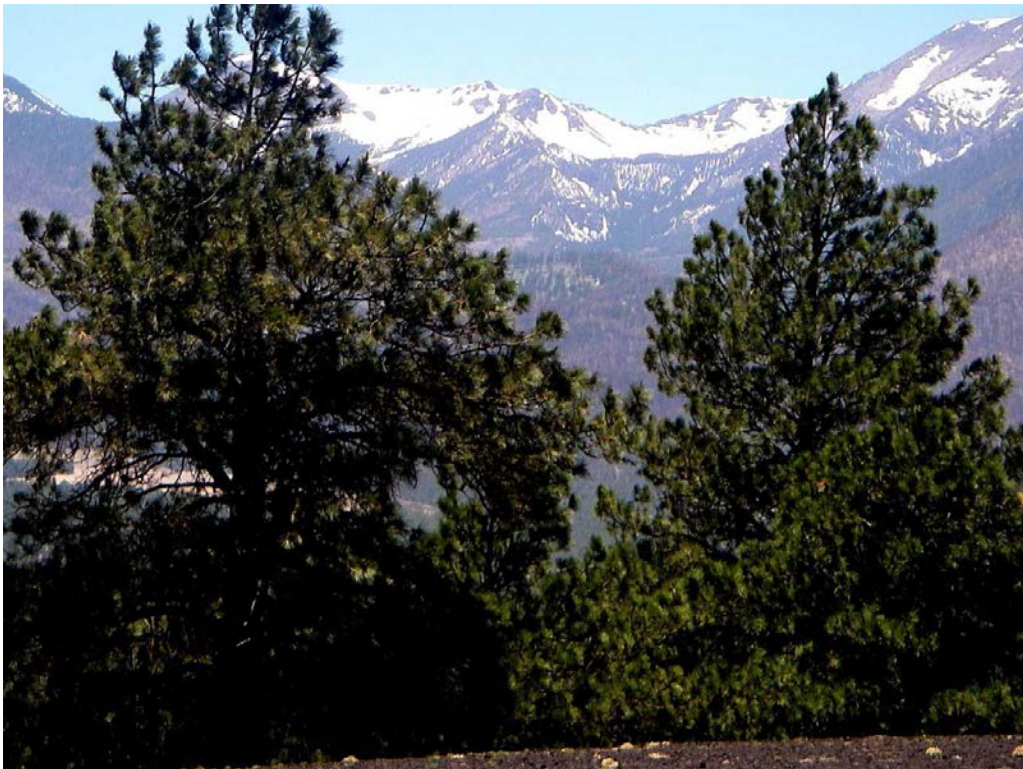


Figure 99.—Climate, organisms, topography, parent material, and time influence soil development. The events that formed this scene have taken place over a long period of time. Kana`a-Cinder land complex, 15 to 60 percent slopes (map unit 26) is in the foreground.

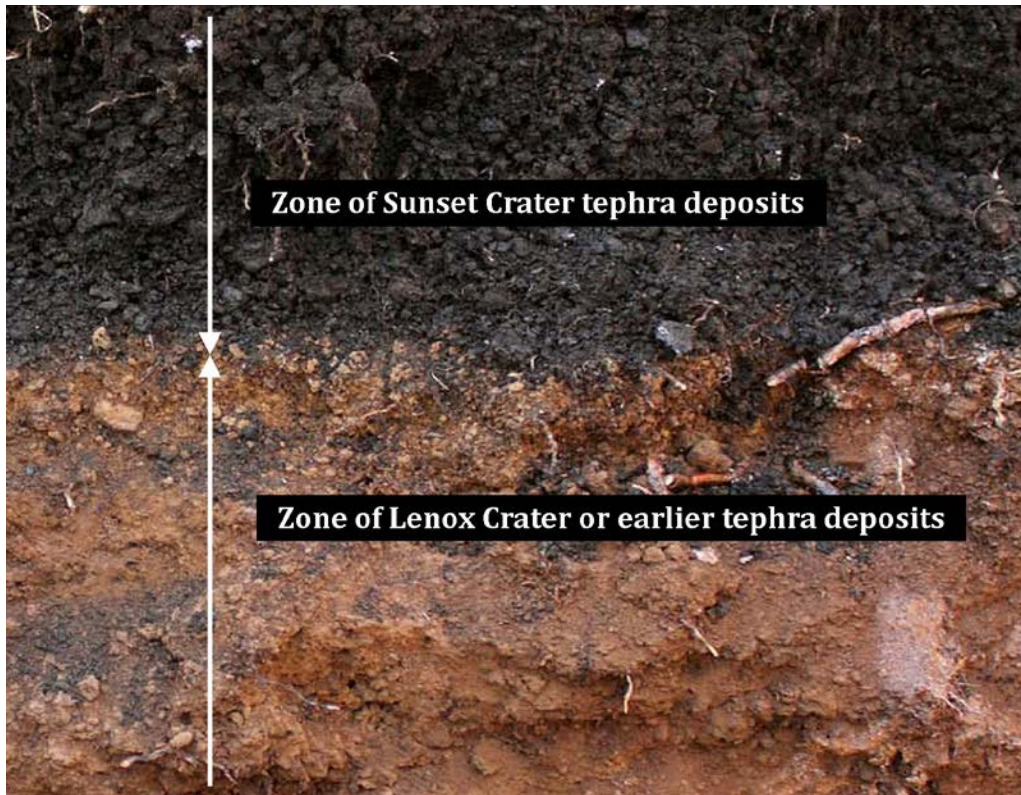


Figure 100.—Profile of Sunsetcrater soil showing the relationship between tephra deposited by recent Sunset Crater eruptive episodes of Sunset Crater and older eruptions originating from other cinder cones. The earlier tephra deposits may have originated from the event that formed the Lenox Crater cinder cone. The cinders from the earlier explosion have been oxidized and thus appear red from coatings of mineral hematite. The overlying, younger Sunset Crater tephra appear black from uncoated volcanic glass, mineral feldspars, and other volcanic minerals. In a matter of thousands of years, the cinders of Sunset Crater may also become coated with hematite and thus match in color the older cinders. This Sunsertcrater soil is in map unit 30 (Sunsetcrater extremely gravelly loamy sand, 15 to 35 percent slopes).

interaction of the soil-forming factors with one or more of the soil-forming processes (Simonson, 1959).

When mapping soils, a soil scientist looks for areas with similar soil-forming factors to find similar soils. The properties of the soils are described. Soils with the same kind of properties are given taxonomic names. Soils are classified, mapped, and interpreted on the basis of various kinds of soil horizons and their arrangement. The distribution of soil orders corresponds with the general patterns of the soil-forming factors within the park.

The system of soil classification used by the National Cooperative Soil Survey has six categories (Soil Survey Staff, 1999 and 2010). Beginning with the broadest, these categories are the order, suborder, great group, subgroup, family, and series. Classification is based on soil properties observed in the field or inferred from those observations or from laboratory measurements. The categories are defined in the following paragraphs.

ORDER. Soil taxonomy at the highest hierarchical level identifies 12 soil orders. The names for the orders and taxonomic soil properties relate to Greek, Latin, or other root words that reveal something about the soil. The differences among orders reflect the dominant soil-forming processes and the degree of soil formation. Each order is identified by a word ending in *sol*. An example is Entisol.

SUBORDER. Each order is divided into suborders primarily on the basis of properties that influence soil genesis and are important to plant growth or properties that reflect the most important variables within the orders. Sixty-four suborders are recognized at the next level of classification. The last syllable in the name of a suborder indicates the order. An example is Orthent (*Orth*, meaning young soil that lacks horizonation, plus *ent*, from Entisol).

GREAT GROUP. Each suborder is divided into great groups on the basis of close similarities in kind, arrangement, and degree of development of pedogenic horizons; soil moisture and temperature regimes; type of saturation; and base status. There are about 300 great groups. Each great group is identified by the name of a suborder and by a prefix that indicates a property of the soil. An example is Ustorthent (*Ust*, indicating soil with an ustic moisture regime, plus *orthent*, the suborder of the Entisols that lacks horizonation or development).

SUBGROUP. There are more than 2,400 subgroups. Each great group has a typic subgroup. The typic subgroup is the central concept of the great group; it is not necessarily the most extensive. Other subgroups are intergrades or extragrades. Intergrades are transitions to other orders, suborders, or great groups. Extragrades have some properties that are not representative of the great group but do not indicate transitions to any other taxonomic class. Each subgroup is identified by one or more adjectives preceding the name of the great group. The adjective *Vitrandid* identifies the subgroup that is comprised of volcanic deposits or has a layer of pyroclastic materials. An example is Vitrandid Ustorthents.

FAMILY. Families are established within a subgroup on the basis of physical and chemical properties and other characteristics that affect management. Generally, the properties for family placement are those of horizons below a traditional agronomic plow depth. Among the properties and characteristics considered are particle-size class, mineralogy class, cation-exchange activity class, soil temperature regime, soil depth, and reaction class. A family name consists of the name of a subgroup preceded by terms that indicate soil properties. An example is ashy, glassy, nonacid, frigid Vitrandid Ustorthents.

SERIES. The soil series is the lowest category in the soil classification system. The series consists of soils within a family that have horizons similar in color, texture, structure, reaction, consistence, mineral and chemical composition, and arrangement in the profile. An example is the Blackash series, which is classified as a ashy, glassy, nonacid, frigid Vitrandid Ustorthent. The Blackash series is unique to Sunset Crater Volcano National Monument and was named after a lava flow near the soil type location.

Most parks are mapped to the series level. The names of soil series are selected by the soil scientists during the course of mapping. The series names are commonly geographic place names or are coined. Because of access limitations and soil variability, soils in some remote areas are classified at the great group or subgroup level.

Table 28 indicates the order, suborder, great group, subgroup, and family of the soil series in the park. Table 29 displays the classification as a key sorted by order.

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Glossary

Many of the terms relating to landforms, geology, and geomorphology are defined in more detail in the “National Soil Survey Handbook” (available in local offices of the Natural Resources Conservation Service or on the Internet).

`a`a lava. Hawaiian term for basaltic lava having a rough, jagged, clinkery surface and a vesicular interior.

`a`a lava flow. Basaltic lava flow dominated by `a`a lava that has a characteristically rough, jagged, clinkery surface.

Aeration, soil. The exchange of air in soil with air from the atmosphere. The air in a well aerated soil is similar to that in the atmosphere; the air in a poorly aerated soil is considerably higher in carbon dioxide and lower in oxygen.

Agglutinate mound. A mound of cinders that has been carried away, as on a raft, from the original site of a cinder cone eruption.

Aggregate, soil. Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

Alkali (sodic) soil. A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

Alluvial fan. A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes. It is shaped like an open fan or a segment of a cone. The material was deposited by a stream at the place where it issues from a narrow mountain valley or upland valley or where a tributary stream is near or at its junction with the main stream. The fan is steepest near its apex, which points upstream, and slopes gently and convexly outward (downstream) with a gradual decrease in gradient.

Alluvium. Unconsolidated material, such as gravel, sand, silt, clay, and various mixtures of these, deposited on land by running water.

Aquic conditions. Current soil wetness characterized by saturation, reduction, and redoximorphic features.

Argillic horizon. A subsoil horizon characterized by an accumulation of illuvial clay.

Ash (volcanic). Unconsolidated, pyroclastic material less than 2 mm in all dimensions. Commonly called “volcanic ash.”

Ash flow. (Note: This term is not preferred; see Pyroclastic flow and Pyroclastic surge.) A highly heated mixture of volcanic gases and ash, traveling down the flank of a volcano or along the surface of the ground; produced by the explosive disintegration of viscous lava in a volcanic crater, or by the explosive emission of gas-charged ash from a fissure or group of fissures. The solid materials contained in a typical ash flow are generally unsorted and ordinarily include volcanic dust, pumice, scoria, and blocks in addition to ash. Also called pyroclastic flow.

Aspect. The direction toward which a slope faces. Also called slope aspect.

Available water capacity (available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at

wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile or to a limiting layer is expressed as:

Very low	0 to 3
Low	3 to 6
Moderate.....	6 to 9
High	9 to 12
Very high.....	more than 12

Backslope. The position that forms the steepest and generally linear, middle portion of a hillslope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below.

Badland. A landscape that is intricately dissected and characterized by a very fine drainage network with high drainage densities and short, steep slopes and narrow interfluvies. Badlands develop on surfaces that have little or no vegetative cover overlying unconsolidated or poorly cemented materials (clays, silts, or sandstones) with, in some cases, soluble minerals, such as gypsum or halite.

Base saturation. The degree to which material having cation-exchange properties is saturated with exchangeable bases (sum of Ca, Mg, Na, and K), expressed as a percentage of the total cation-exchange capacity.

Base slope (geomorphology). A geomorphic component of hills consisting of the concave to linear (perpendicular to the contour) slope that, regardless of the lateral shape, forms an apron or wedge at the bottom of a hillside dominated by colluvium and slope-wash sediments (for example, slope alluvium).

Bedrock. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Bedrock-controlled topography. A landscape where the configuration and relief of the landforms are determined or strongly influenced by the underlying bedrock

Block field. A thin accumulation of typically angular stone blocks that has only coarse fragments in the upper part and overlies solid or weathered bedrock, colluvium, or alluvium where there is not a cliff or ledge above as an apparent source. Block fields occur on high mountain slopes above the tree-line or in polar or paleo-periglacial regions. They are most extensive along slopes parallel to the contour, and they generally occur on slopes of less than 5 percent.

Block glide (mass movement). A slow type of landslide in which largely intact units (blocks) of rock or soil slide downslope along a relatively planar surface, such as a bedding plane, without any significant distortion of the original mass; a type of translational rock slide.

Block lava. Lava having a surface of angular blocks that is similar to `a`a lava but has fragments that are larger and more regular in shape, somewhat smoother, and less vesicular. Compare to `a`a lava, pahoehoe lava, and pillow lava.

Block lava flow. A lava flow dominated by block lava. Compare to `a`a lava flow and pahoehoe lava flow.

Bottom land. An informal term loosely applied to various portions of a flood plain.

Boulders. Rock fragments larger than 2 feet (60 centimeters) in diameter.

Bouldery. Refers to a soil containing boulders in numbers that interfere with or prevent tillage.

Calcareous soil. A soil containing enough calcium carbonate (commonly combined with magnesium carbonate) to effervesce visibly when treated with cold, dilute hydrochloric acid.

Caldera. A large, more or less circular depression, which was formed by explosion and/or collapse and which surrounds a volcanic vent or vents. Its diameter is many times greater than that of the included vent or vents.

Canopy. The leafy crown of trees or shrubs. (See Crown.)

Canyon. A long, deep, narrow valley with high, precipitous walls in an area of high local relief.

- Capillary water.** Water held as a film around soil particles and in tiny spaces between particles. Surface tension is the adhesive force that holds capillary water in the soil.
- Catena.** A sequence, or “chain,” of soils on a landscape that formed in similar kinds of parent material but have different characteristics as a result of differences in relief and drainage.
- Cation-exchange capacity.** The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. The term, as applied to soils, is synonymous with base-exchange capacity but is more precise in meaning.
- Channery soil material.** Soil material that has, by volume, 15 to 35 percent thin, flat fragments of sandstone, shale, slate, limestone, or schist as much as 6 inches (15 centimeters) along the longest axis. A single piece is called a chanter.
- Cinder cone.** A conical hill formed by the accumulation of cinders and other pyroclastics, typically basaltic or andesitic in composition. Slopes generally exceed 20 percent.
- Cinders.** Uncemented vitric, vesicular, pyroclastic material that is more than 2.0 millimeters long in at least one dimension and has an apparent specific gravity (including vesicles) of more than 1.0 and less than 2.0.
- Clay.** As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.
- Clay film.** A thin coating of oriented clay on the surface of a soil aggregate or lining pores or root channels. Synonyms: clay coating, clay skin.
- Coarse textured soil.** Sand or loamy sand.
- Cobble (or cobblestone).** A rounded or partly rounded fragment of rock 3 to 10 inches (7.6 to 25 centimeters) in diameter.
- Cobbly soil material.** Material that has 15 to 35 percent, by volume, rounded or partially rounded rock fragments 3 to 10 inches (7.6 to 25 centimeters) in diameter. Very cobbly soil material has 35 to 60 percent of these rock fragments, and extremely cobbly soil material has more than 60 percent.
- COLE (coefficient of linear extensibility).** See Linear extensibility.
- Colluvium.** Unconsolidated, unsorted earth material that is transported or deposited on side slopes and/or at the base of slopes by mass movement (e.g., direct gravitational action) and by local, unconcentrated runoff.
- Common resource area.** See Land resource units and Major land resource areas.
- Complex, soil.** A map unit of two or more kinds of soil or miscellaneous areas in such an intricate pattern or so small in area that it is not practical to map them separately at the selected scale of mapping. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas.
- Concretions.** See Redoximorphic features.
- Conglomerate.** A coarse grained, clastic sedimentary rock composed of rounded or subangular rock fragments more than 2 millimeters in diameter. It commonly has a matrix of sand and finer textured material. Conglomerate is the consolidated equivalent of gravel.
- Consistence, soil.** Refers to the degree of cohesion and adhesion of soil material and its resistance to deformation when ruptured. Consistence includes resistance of soil material to rupture and to penetration; plasticity, toughness, and stickiness of puddled soil material; and the manner in which the soil material behaves when subject to compression. Terms describing consistence are defined in the “Soil Survey Manual.”
- Control section.** The part of the soil on which classification is based. The thickness varies among different kinds of soil, but for many it is that part of the soil profile between depths of 10 inches and 40 or 80 inches.

- Corrosion (geomorphology).** A process of erosion whereby rocks and soil are removed or worn away by natural chemical processes, especially by the solvent action of running water, but also by other reactions, such as hydrolysis, hydration, carbonation, and oxidation.
- Corrosion** (soil survey interpretations). Soil-induced electrochemical or chemical action that dissolves or weakens concrete or uncoated steel.
- Crown.** The upper part of a tree or shrub, including the living branches and their foliage.
- Cumulization (soil formation).** The process in which fine grains accumulate on surface from wind or water action and simultaneously penetrate the upper portion of a soil profile with precipitation events.
- Dense layer** (in tables). A very firm, massive layer that has a bulk density of more than 1.8 grams per cubic centimeter. Such a layer affects the ease of digging and can affect filling and compacting.
- Densic materials.** Materials that are relatively unaltered and have a noncemented rupture-resistance class. The bulk density or the organization is such that roots cannot enter, except in cracks. These are mostly earthy materials, such as till, volcanic mudflows, and some mechanically compacted materials, such as mine spoils. Some noncemented rocks can be densic materials if they are dense or resistant enough to keep roots from entering, except in cracks.
- Depth, soil.** Generally, the thickness of the soil over bedrock. Very deep soils are more than 60 inches deep over bedrock; deep soils, 40 to 60 inches; moderately deep, 20 to 40 inches; shallow, 10 to 20 inches; and very shallow, less than 10 inches.
- Drainage class (natural).** Refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized—*excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained*. These classes are defined in the “Soil Survey Manual.”
- Drainage, surface.** Runoff, or surface flow of water, from an area.
- Drainageway.** A general term for a course or channel along which water moves in draining an area. A term restricted to relatively small, linear depressions that at some time move concentrated water and either do not have a defined channel or have only a small defined channel.
- Dune.** A low mound, ridge, bank, or hill of loose, windblown granular material (generally sand). It is either barren and capable of movement from place to place or is covered and stabilized with vegetation but still retaining its characteristic shape.
- Ecological site.** An area where climate, soil, and relief are sufficiently uniform to produce a distinct natural plant community. An ecological site is the product of all the environmental factors responsible for its development. It is typified by an association of species that differ from those on other ecological sites in kind and/or proportion of species or in total production.
- Eolian deposit.** Sand-, silt-, or clay-sized clastic material transported and deposited primarily by wind, commonly in the form of a dune or a sheet of sand or loess.
- Ephemeral stream.** A stream, or reach of a stream, that flows only in direct response to precipitation. It receives no long-continued supply from melting snow or other source, and its channel is above the water table at all times.
- Erosion (accelerated).** Erosion much more rapid than geologic erosion, mainly as a result of human or animal activities or of a catastrophe in nature, such as a fire, that exposes the surface.

- Erosion (geologic).** Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.
- Erosion surface.** A land surface shaped by the action of erosion, especially by running water.
- Escarpment.** A relatively continuous and steep slope or cliff breaking the general continuity of more gently sloping land surfaces and resulting from erosion or faulting. Most commonly applied to cliffs produced by differential erosion. Synonym: scarp.
- Extrusive.** Term used for igneous rocks and sediments derived from deep-seated molten matter (magma) deposited and cooled on the earth's surface. Examples are lava flows and tephra deposits.
- Fan remnant.** A general term for landforms that are the remaining parts of older fan landforms, such as alluvial fans, that have been either dissected or partially buried.
- Field moisture capacity.** The moisture content of a soil, expressed as a percentage of the oven-dry weight, after the gravitational, or free, water has drained away; the field moisture content 2 or 3 days after a soaking rain; also called normal field capacity, normal moisture capacity, or capillary capacity.
- Fill slope.** A sloping surface consisting of excavated soil material from a road cut. It commonly is on the downhill side of the road.
- Fine textured soil.** Sandy clay, silty clay, or clay.
- Fissure vent.** An opening in the earth's surface of a volcanic conduit in the form of a crack or fissure rather than a localized crater; a roughly linear crack or area along which lava, generally mafic and of low viscosity, wells up to the surface, usually without any explosive activity. The results include an extensive lava plateau, such as the Columbia River Plateau.
- Flagstone.** A thin fragment of sandstone, limestone, slate, shale, or (rarely) schist 6 to 15 inches (15 to 38 centimeters) long.
- Flood plain.** The nearly level plain that borders a stream and is subject to flooding unless protected artificially.
- Flood-plain step.** An essentially flat, terrace-like alluvial surface within a valley that is frequently covered by floodwater from the present stream; any approximately horizontal surface still actively modified by fluvial scour and/or deposition. Flood-plain steps may occur individually or as a series of steps.
- Fluvial.** Of or pertaining to rivers or streams; produced by stream or river action.
- Foothills.** A region of steeply sloping hills that fringes a mountain range or high-plateau escarpment. The hills have relief of as much as 1,000 feet (300 meters).
- Footslope.** The concave surface at the base of a hillslope. A footslope is a transition zone between upslope sites of erosion and transport (shoulders and backslopes) and downslope sites of deposition (toeslopes).
- Forb.** Any herbaceous plant not a grass or a sedge.
- Forest cover.** All trees and other woody plants (underbrush) covering the ground in a forest.
- Forest type.** A stand of trees similar in composition and development because of given physical and biological factors by which it may be differentiated from other stands.
- Gravel.** Rounded or angular fragments of rock as much as 3 inches (2 millimeters to 7.6 centimeters) in diameter. An individual piece is a pebble.
- Gravelly soil material.** Material that has 15 to 35 percent, by volume, rounded or angular rock fragments, not prominently flattened, as much as 3 inches (7.6 centimeters) in diameter.
- Ground water.** Water filling all the unblocked pores of the material below the water table.

Gully. A small channel with steep sides caused by erosion and cut in unconsolidated materials by concentrated but intermittent flow of water. The distinction between a gully and a rill is one of depth. A gully generally is an obstacle to farm machinery and is too deep to be obliterated by ordinary tillage; a rill is of lesser depth and can be smoothed over by ordinary tillage.

Hard bedrock. Bedrock that cannot be excavated except by blasting or by the use of special equipment that is not commonly used in construction.

Hard to reclaim (in tables). Reclamation is difficult after the removal of soil for construction and other uses. Revegetation and erosion control are extremely difficult.

Hardpan. A hardened or cemented soil horizon, or layer. The soil material is sandy, loamy, or clayey and is cemented by iron oxide, silica, calcium carbonate, or other substance.

Head slope (geomorphology). A geomorphic component of hills consisting of a laterally concave area of a hillside, especially at the head of a drainageway. The overland waterflow is converging.

Hill. A generic term for an elevated area of the land surface, rising as much as 1,000 feet above surrounding lowlands, commonly of limited summit area and having a well defined outline. Slopes are generally more than 15 percent. The distinction between a hill and a mountain is arbitrary and may depend on local usage.

Hillslope. A generic term for the steeper part of a hill between its summit and the drainage line, valley flat, or depression floor at the base of a hill.

Horizon, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. In the identification of soil horizons, an uppercase letter represents the major horizons. Numbers or lowercase letters that follow represent subdivisions of the major horizons. An explanation of the subdivisions is given in the "Soil Survey Manual." The major horizons of mineral soil are as follows:

A horizon.—The mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material. Also, a plowed surface horizon, most of which was originally part of a B horizon.

B horizon.—The mineral horizon below an A horizon. The B horizon is in part a layer of transition from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics, such as (1) accumulation of clay, sesquioxides, humus, or a combination of these; (2) prismatic or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these.

C horizon.—The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the overlying soil material. The material of a C horizon may be either like or unlike that in which the solum formed. If the material is known to differ from that in the solum, an Arabic numeral, commonly a 2, precedes the letter C.

Cr horizon.—Soft, consolidated bedrock beneath the soil.

R layer.—Consolidated bedrock beneath the soil. The bedrock commonly underlies a C horizon, but it can be directly below an A or a B horizon.

Hydrologic soil groups. Refers to soils grouped according to their runoff potential.

The soil properties that influence this potential are those that affect the minimum rate of water infiltration on a bare soil during periods after prolonged wetting when the soil is not frozen. These properties are depth to a seasonal high water table, the infiltration rate and permeability after prolonged wetting, and depth to a very slowly permeable layer. The slope and the kind of plant cover are not considered but are separate factors in predicting runoff.

Infiltration rate. The rate at which water penetrates the surface of the soil at any given instant, usually expressed in inches per hour. The rate can be limited by the infiltration capacity of the soil or the rate at which water is applied at the surface.

Interfluve (geomorphology). A geomorphic component of hills consisting of the uppermost, comparatively level or gently sloping area of a hill; shoulders of backwearing hillslopes can narrow the upland or can merge, resulting in a strongly convex shape.

Intermittent stream. A stream, or reach of a stream, that does not flow year-round but that is commonly dry for 3 or more months out of 12 and whose channel is generally below the local water table. It flows only during wet periods or when it receives ground-water discharge or long, continued contributions from melting snow or other surface and shallow subsurface sources.

Iron depletions. See Redoximorphic features.

K_{sat} . Saturated hydraulic conductivity. (See Permeability.)

Lacustrine deposit. Material deposited in lake water and exposed when the water level is lowered or the elevation of the land is raised.

Land resource units (LRUs). The basic units from which major land resource areas (MLRAs) are determined. LRUs are created by subdividing MLRAs according to concerns for resources, soil groups, hydrologic units, topography and other landscape features, and considerations for land use and soil and water conservation treatment. Also referred to as common resource area (CRA).

Landslide. A general, encompassing term for most types of mass movement landforms and processes involving the downslope transport and outward deposition of soil and rock materials caused by gravitational forces; the movement may or may not involve saturated materials. The speed and distance of movement, as well as the amount of soil and rock material, vary greatly.

Large stones (in tables). Rock fragments 3 inches (7.6 centimeters) or more across. Large stones adversely affect the specified use of the soil.

Lava. A general term for a molten extrusive; also the rock solidified from it.

Lava channel. See Lava trench.

Lava field. An area covered primarily by lava flows whose terrain can be rough and broken or relatively smooth; it can include vent structures (e.g., small cinder cones and spatter cones), surface flow structures (e.g., pressure ridges and tumuli), and small, intermittent areas covered with pyroclastics.

Lava flow. A solidified body of rock formed from the lateral, surficial outpouring of molten lava from a vent or fissure. It is commonly lobate in form. Compare to `a`a lava flow, lava flow unit, and pahoehoe lava flow.

Lava flow unit. A separate, distinct lobe of lava that issues from the main body of a lava flow; a specific outpouring of lava a few centimeters to several meters thick and of variable lateral extent that forms a subdivision within a single flow. A series of overlapping lava flow units comprise a single lava flow. Also called flow unit.

Lava plain. A broad area of nearly level land that can be localized but is commonly hundreds of square kilometers in extent and that is covered by a relatively thin succession of primarily basaltic lava flows resulting from fissure eruptions.

Lava plateau. A broad elevated tableland or flat-topped highland that may be localized but commonly is many hundreds or thousands of square kilometers in extent and that is underlain by a thick succession of basaltic lavafloes resulting from fissure eruptions (e.g., the Columbia River Plateau).

Lava trench. A natural surface channel in a lava flow that never had a roof and was formed by the surficial draining of molten lava rather than by erosion from running water. Also called lava channel.

Lava tube. A natural, hollow tunnel beneath the surface of a solidified lava flow through which the lava flow was fed. The tunnel was left empty when the molten lava drained out.

Leaching. The removal of soluble material from soil or other material by percolating water.

- Ledge.** A narrow shelf or projection of rock, much longer than wide, formed on a rock wall or cliff face.
- Linear extensibility.** Refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. Linear extensibility is used to determine the shrink-swell potential of soils. It is an expression of the volume change between the water content of the clod at $1/3$ - or $1/10$ -bar (33kPa or 10kPa) tension and oven dryness. Volume change is influenced by the amount and type of clay minerals in the soil. The volume change is the percent change for the whole soil. If it is expressed as a fraction, the resulting value is COLE, coefficient of linear extensibility.
- Liquid limit.** The moisture content at which the soil passes from a plastic to a liquid state.
- Loam.** Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.
- Low strength.** The soil is not strong enough to support loads.
- Mafic rock.** A general term for igneous rock composed chiefly of one or more ferromagnesian, dark-colored minerals; also said of those minerals.
- Major land resource areas (MLRAs).** These are geographically associated land resource units (LRUs). Identification of these large areas is important in statewide agricultural planning as well as in interstate, regional, and national planning.
- Marl.** An earthy, unconsolidated deposit consisting chiefly of calcium carbonate mixed with clay in approximately equal proportions; formed primarily under freshwater lacustrine conditions but also in more saline environments.
- Mass movement.** A generic term for the dislodgment and downslope transport of soil and rock material as a unit under direct gravitational stress.
- Masses.** See Redoximorphic features.
- Mawae** (colloquial Hawaiian term). A natural surface channel that commonly occurs near the middle of an `a`a lava flow and that formed by the surficial draining of molten lava rather than by erosion from running water; a type of lava trench.
- Medium textured soil.** Very fine sandy loam, loam, silt loam, or silt.
- Mesa.** A broad, nearly flat-topped and commonly isolated landmass bounded by steep slopes or precipitous cliffs and capped by layers of resistant, nearly horizontal rocky material. The summit width is characteristically greater than the height of the bounding escarpments.
- Metamorphic rock.** Rock of any origin altered in mineralogical composition, chemical composition, or structure by heat, pressure, and movement at depth in the earth's crust. Nearly all such rocks are crystalline.
- Mineral soil.** Soil that is mainly mineral material and low in organic material. Its bulk density is more than that of organic soil.
- Miscellaneous area.** A kind of map unit that has little or no natural soil and supports little or no vegetation.
- Moderately coarse textured soil.** Coarse sandy loam, sandy loam, or fine sandy loam.
- Moderately fine textured soil.** Clay loam, sandy clay loam, or silty clay loam.
- Morphology, soil.** The physical makeup of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.
- Mottling, soil.** Irregular spots of different colors that vary in number and size. Descriptive terms are as follows: abundance—*few*, *common*, and *many*; size—*fine*, *medium*, and *coarse*; and contrast—*faint*, *distinct*, and *prominent*. The size measurements are of the diameter along the greatest dimension. Fine indicates less than 5 millimeters (about 0.2 inch); medium, from 5 to 15 millimeters (about 0.2 to 0.6 inch); and coarse, more than 15 millimeters (about 0.6 inch).

Mountain. A generic term for an elevated area of the land surface, rising more than 1,000 feet (300 meters) above surrounding lowlands, commonly of restricted summit area (relative to a plateau) and generally having steep sides. A mountain can occur as a single, isolated mass or in a group forming a chain or range. Mountains are formed primarily by tectonic activity and/or volcanic action but can also be formed by differential erosion.

Mudstone. A blocky or massive, fine grained sedimentary rock in which the proportions of clay and silt are approximately equal. Also, a general term for such material as clay, silt, claystone, siltstone, shale, and argillite and that should be used only when the amounts of clay and silt are not known or cannot be precisely identified.

Munsell notation. A designation of color by degrees of three simple variables—*hue*, *value*, and *chroma*. For example, a notation of 10YR 6/4 is a color with hue of 10YR, value of 6, and chroma of 4.

Neutral soil. A soil having a pH value of 6.6 to 7.3. (See Reaction, soil.)

Nodules. See Redoximorphic features.

Nose slope (geomorphology). A geomorphic component of hills consisting of the projecting end (laterally convex area) of a hillside. The overland waterflow is predominantly divergent. Nose slopes consist dominantly of colluvium and slope-wash sediments (for example, slope alluvium).

Organic matter. Plant and animal residue in the soil in various stages of decomposition. The content of organic matter in the surface layer is described as follows:

Very low	less than 0.5 percent
Low	0.5 to 1.0 percent
Moderately low.....	1.0 to 2.0 percent
Moderate.....	2.0 to 4.0 percent
High	4.0 to 8.0 percent
Very high.....	more than 8.0 percent

Pahoehoe lava. Basaltic lava that has a characteristically smooth, billowy or rope-like surface and vesicular interior.

Pahoehoe lava flow. Basaltic lava flow that has a characteristically smooth, billowy or rope-like surface.

Parent material. The unconsolidated organic and mineral material in which soil forms.

Ped. An individual natural soil aggregate, such as a granule, a prism, or a block.

Pedon. The smallest volume that can be called “a soil.” A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 10 to 100 square feet (1 square meter to 10 square meters), depending on the variability of the soil.

Percolation. The movement of water through the soil.

Permeability. The quality of the soil that enables water or air to move downward through the profile. The rate at which a saturated soil transmits water is accepted as a measure of this quality. In soil physics, the rate is referred to as “saturated hydraulic conductivity,” which is defined in the “Soil Survey Manual.” In line with conventional usage in the engineering profession and with traditional usage in published soil surveys, this rate of flow continues to be expressed as “permeability.” Terms describing permeability, measured in inches per hour, are as follows:

Impermeable.....	less than 0.0015 inch
Very slow	0.0015 to 0.06 inch
Slow	0.06 to 0.2 inch
Moderately slow.....	0.2 to 0.6 inch
Moderate.....	0.6 inch to 2.0 inches
Moderately rapid	2.0 to 6.0 inches
Rapid	6.0 to 20 inches
Very rapid.....	more than 20 inches

pH value. A numerical designation of acidity and alkalinity in soil. (See Reaction, soil.)

Phase, soil. A subdivision of a soil series based on features that affect its use and management, such as slope, stoniness, and flooding.

Pillow lava. A general term for lava displaying pillow structure (discontinuous, close-fitting, bun-shaped or ellipsoidal masses generally less than 1 meter in diameter). It is considered to have formed in a subaqueous environment. Such lava is typically basaltic or andesitic.

Pillow lava flow. A lava flow or body displaying pillow structure and considered to have formed in a subaqueous environment; typically basaltic or andesitic in composition. Compare to block lava flow and pahoehoe lava flow.

Plastic limit. The moisture content at which a soil changes from semisolid to plastic.

Plasticity index. The numerical difference between the liquid limit and the plastic limit; the range of moisture content within which the soil remains plastic.

Plateau (geomorphology). A comparatively flat area of great extent and elevation; specifically, an extensive land region that is considerably elevated (more than 100 meters) above the adjacent lower-lying terrain, is commonly limited on at least one side by an abrupt descent, and has a flat or nearly level surface. A comparatively large part of a plateau surface is near summit level.

Ponding. Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.

Poorly graded. Refers to a coarse grained soil or soil material consisting mainly of particles of nearly the same size. Because there is little difference in size of the particles, density can be increased only slightly by compaction.

Pore linings. See Redoximorphic features.

Potential rooting depth (effective rooting depth). Depth to which roots could penetrate if the content of moisture in the soil were adequate. The soil has no properties restricting the penetration of roots to this depth.

Productivity, soil. The capability of a soil for producing a specified plant or sequence of plants under specific management.

Profile, soil. A vertical section of the soil extending through all its horizons and into the parent material.

Proper grazing use. Grazing at an intensity that maintains enough cover to protect the soil and maintain or improve the quantity and quality of the desirable vegetation. This practice increases the vigor and reproduction capacity of the key plants and promotes the accumulation of litter and mulch necessary to conserve soil and water.

Pumice (geology). Rock fragments or coherent rock layers (pumice flow) composed of light-colored, vesicular, glassy rock commonly having the composition of rhyolite. The material commonly has a specific gravity of less than 1.0 and is thereby sufficiently buoyant to float on water. There are no size restrictions.

Pumice (soil science). Rock fragments that are 2 millimeters in diameter or coherent rock layers (pumice flow) composed of light-colored, vesicular, glassy rock commonly having the composition of rhyolite. The material commonly has a specific gravity of less than 1.0 and is thereby sufficiently buoyant to float on water.

Pyroclastic. Pertaining to clastic rock particles produced by explosive, aerial ejection from a volcanic vent. Such materials may accumulate on land or under water. Compare to volcaniclastic.

Pyroclastic flow. A fast-moving current of pyroclastic material, usually very hot, composed of a mixture of gasses and a variety of pyroclastic particles (such as ash, pumice, scoria, and lava fragments). It is produced by the explosive disintegration of viscous lava in a volcanic crater or by the explosive emission of gas-charged ash from a fissure and tends to follow topographic lows (e.g., valleys) as it moves. This term is used in a more general sense than ash flow.

Pyroclastic surge. A low-density, dilute, turbulent pyroclastic flow, usually very hot, composed of a generally unsorted mixture of gases, ash, pumice, and dense rock fragments that travels across the ground at high speeds and is less constrained by topography than a pyroclastic flow. There are several types of pyroclastic surges, including base surge and ash-cloud surge.

Rangeland. Land on which the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing. It includes natural grasslands, savannas, many wetlands, some deserts, tundras, and areas that support certain forb and shrub communities.

Reaction, soil. A measure of acidity or alkalinity of a soil, expressed as pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degrees of acidity or alkalinity, expressed as pH values, are:

Ultra acid.....	less than 3.5
Extremely acid	3.5 to 4.4
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Moderately acid	5.6 to 6.0
Slightly acid.....	6.1 to 6.5
Neutral	6.6 to 7.3
Slightly alkaline.....	7.4 to 7.8
Moderately alkaline.....	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline.....	9.1 and higher

Red beds. Sedimentary strata that are mainly red and are made up largely of sandstone and shale.

Redoximorphic concentrations. See Redoximorphic features.

Redoximorphic depletions. See Redoximorphic features.

Redoximorphic features. Redoximorphic features are associated with wetness and result from alternating periods of reduction and oxidation of iron and manganese compounds in the soil. Reduction occurs during saturation with water, and oxidation occurs when the soil is not saturated. Characteristic color patterns are created by these processes. The reduced iron and manganese ions may be removed from a soil if vertical or lateral fluxes of water occur, in which case there is no iron or manganese precipitation in that soil. Wherever the iron and manganese are oxidized and precipitated, they form either soft masses or hard concretions or nodules. Movement of iron and manganese as a result of redoximorphic processes in a soil may result in redoximorphic features that are defined as follows:

1. Redoximorphic concentrations.—These are zones of apparent accumulation of iron-manganese oxides, including:
 - A. Nodules and concretions, which are cemented bodies that can be removed from the soil intact. Concretions are distinguished from nodules on the basis of internal organization. A concretion typically has concentric layers that are visible to the naked eye. Nodules do not have visible organized internal structure; *and*
 - B. Masses, which are noncemented concentrations of substances within the soil matrix; *and*
 - C. Pore linings, i.e., zones of accumulation along pores that may be either coatings on pore surfaces or impregnations from the matrix adjacent to the pores.
2. Redoximorphic depletions.—These are zones of low chroma (chromas less than those in the matrix) where either iron-manganese oxides alone or both iron-manganese oxides and clay have been stripped out, including:
 - A. Iron depletions, i.e., zones that contain low amounts of iron and manganese oxides but have a clay content similar to that of the adjacent matrix; *and*

B. Clay depletions, i.e., zones that contain low amounts of iron, manganese, and clay (often referred to as silt coatings or skeletans).

3. Reduced matrix.—This is a soil matrix that has low chroma *in situ* but undergoes a change in hue or chroma within 30 minutes after the soil material has been exposed to air.

Reduced matrix. See Redoximorphic features.

Relief. The relative difference in elevation between the upland summits and the lowlands or valleys of a given region.

Residuum (residual soil material). Unconsolidated, weathered or partly weathered mineral material that accumulated as bedrock disintegrated in place.

Riser. The vertical or steep side slope (e.g., escarpment) of terraces, flood-plain steps, or other stepped landforms; commonly a recurring part of a series of natural, steplike landforms, such as successive stream terraces.

Road cut. A sloping surface produced by mechanical means during road construction. It is commonly on the uphill side of the road.

Rock fragments. Rock or mineral fragments having a diameter of 2 millimeters or more; for example, pebbles, cobbles, stones, and boulders.

Rock varnish. A thin, dark, shiny film or coating, composed of iron oxide accompanied by traces of manganese oxide and silica, that formed on the surfaces of pebbles, boulders, and other rock fragments. It commonly occurs on rock outcrops in arid regions. It is thought to be caused by exudation of mineralized solutions from within and deposition by evaporation on the surface.

Rocky. A term used in the phase name of soil map unit to indicate areas that have between 0.01 and 10 percent rock outcrop.

Root zone. The part of the soil that can be penetrated by plant roots.

Runoff. The precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called surface runoff. Water that enters the soil before reaching surface streams is called ground-water runoff or seepage flow from ground water.

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Sandstone. Sedimentary rock containing dominantly sand-sized particles.

Saturated hydraulic conductivity (K_{sat}). See Permeability.

Saturation. Wetness characterized by zero or positive pressure of the soil water. Under conditions of saturation, the water will flow from the soil matrix into an unlined auger hole.

Scarp. An escarpment, cliff, or steep slope of some extent along the margin of a plateau, mesa, terrace, or structural bench. A scarp may be of any height.

Scarp slope. The relatively steeper face of a cuesta, facing in a direction opposite to the dip of the strata.

Scoria (geology) Vesicular rock fragments that have a specific gravity of more than 2.0 or a cindery crust of such material on the surface of andesitic or basaltic lava. There are no size restrictions. The vesicular nature is due to the escape of volcanic gases before solidification. It is typically heavier, darker, and more crystalline than pumice.

Scoria (soil science). Vesicular rock fragments that are more than 2 millimeters in size in at least one dimension and have a specific gravity of more than 2.0, or a cindery crust of such material on the surface of andesitic or basaltic lava. The vesicular nature is due to the escape of volcanic gases before solidification. It is typically heavier, darker, and more crystalline than pumice.

Scree. A collective term for an accumulation of coarse rock debris or a sheet of coarse debris mantling a slope. Scree is not synonymous with talus as scree includes loose, coarse fragments on slopes without cliffs.

- Scree slope.** A portion of a hillside or mountain slope mantled by scree and lacking an up-slope rockfall source (i.e., cliff). Compare to scree and talus.
- Sedimentary rock.** A consolidated deposit of clastic particles, chemical precipitates, or organic remains accumulated at or near the surface of the earth under normal low temperature and pressure conditions. Sedimentary rocks include consolidated equivalents of alluvium, colluvium, drift, and eolian, lacustrine, and marine deposits. Examples are sandstone, siltstone, mudstone, claystone, shale, conglomerate, limestone, dolomite, and coal.
- Series, soil.** A group of soils that have profiles that are almost alike, except for differences in texture of the surface layer. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.
- Shale.** Sedimentary rock that formed by the hardening of a deposit of clay, silty clay, or silty clay loam and that has a tendency to split into thin layers.
- Sheet erosion.** The removal of a fairly uniform layer of soil material from the land surface by the action of rainfall and surface runoff.
- Shoulder.** The convex, erosional surface near the top of a hillslope. A shoulder is a transition from summit to backslope.
- Shrink-swell** (in tables). The shrinking of soil when dry and the swelling when wet. Shrinking and swelling can damage roads, dams, building foundations, and other structures. It can also damage plant roots.
- Side slope (geomorphology).** A geomorphic component of hills consisting of a laterally planar area of a hillside. The overland waterflow is predominantly parallel. Side slopes are dominantly colluvium and slope-wash sediments.
- Silt.** As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.
- Siltstone.** An indurated silt having the texture and composition of shale but lacking its fine lamination or fissility; a massive mudstone in which silt predominates over clay.
- Similar soils.** Soils that share limits of diagnostic criteria, behave and perform in a similar manner, and have similar conservation needs or management requirements for the major land uses in the survey area.
- Slickensides (pedogenic).** Grooved, striated, and/or glossy (shiny) slip faces on structural peds, such as wedges; produced by shrink-swell processes, most commonly in soils that have a high content of expansive clays.
- Slick rock.** A barren, highly smoothed and subrounded bedrock pavement with considerable, irregular topography sculpted primarily by wind in an arid climate; a type of rock outcrop common on the top of massive sandstone bedrock, especially on summits of ridges and near the leading edge of plateaus, mesas, and cuestas.
- Slope.** The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.
- Slope alluvium.** Sediment gradually transported down the slopes of mountains or hills primarily by nonchannel alluvial processes (i.e., slope-wash processes) and characterized by particle sorting. Lateral particle sorting is evident on long slopes. In a profile sequence, sediments may be distinguished by differences in size and/or specific gravity of rock fragments and may be separated by stone lines. Burnished peds and sorting of rounded or subrounded pebbles or cobbles distinguish these materials from unsorted colluvial deposits.
- Sodic (alkali) soil.** A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

Sodium adsorption ratio (SAR). A measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration.

Soft bedrock. Bedrock that can be excavated with trenching machines, backhoes, small rippers, and other equipment commonly used in construction.

Soil. A natural, three-dimensional body at the earth's surface. It is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief and the passage of time.

Soil separates. Mineral particles less than 2 millimeters in equivalent diameter and ranging between specified size limits. The names and sizes, in millimeters, of separates recognized in the United States are as follows:

Very coarse sand	2.0 to 1.0
Coarse sand	1.0 to 0.5
Medium sand	0.5 to 0.25
Fine sand	0.25 to 0.10
Very fine sand	0.10 to 0.05
Silt	0.05 to 0.002
Clay.....	less than 0.002

Solum. The upper part of a soil profile, above the C horizon, in which the processes of soil formation are active. The solum in soil consists of the A, E, and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the material below the solum. The living roots and plant and animal activities are largely confined to the solum.

Stones. Rock fragments 10 to 24 inches (25 to 60 centimeters) in diameter if rounded or 15 to 24 inches (38 to 60 centimeters) in length if flat.

Stony. Refers to a soil containing stones in numbers that interfere with or prevent tillage.

Stream terrace. One of a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream; represents the remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of fluvial erosion or deposition.

Structure, soil. The arrangement of primary soil particles into compound particles or aggregates. The principal forms of soil structure are—*platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular*. Structureless soils are either *single grain* (each grain by itself, as in dune sand) or *massive* (the particles adhering without any regular cleavage, as in many hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Substratum. The part of the soil below the solum.

Subsurface layer. Any surface soil horizon (A, E, AB, or EB) below the surface layer.

Summit. The topographically highest position of a hillslope. It has a nearly level (planar or only slightly convex) surface.

Surface layer. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from 4 to 10 inches (10 to 25 centimeters). Frequently designated as the "plow layer," or the "Ap horizon."

Talus. Rock fragments of any size or shape (commonly coarse and angular) derived from and lying at the base of a cliff or very steep rock slope. The accumulated mass of such loose broken rock formed chiefly by falling, rolling, or sliding.

Taxadjuncts. Soils that cannot be classified in a series recognized in the classification system. Such soils are named for a series they strongly resemble and are designated as taxadjuncts to that series because they differ in ways too small to be of consequence in interpreting their use and behavior. Soils are recognized as

taxadjuncts only when one or more of their characteristics are slightly outside the range defined for the family of the series for which the soils are named.

Terrace (geomorphology). A steplike surface, bordering a valley floor or shoreline, that represents the former position of a flood plain, lake, or seashore. The term is usually applied both to the relatively flat summit surface (tread) that was cut or built by stream or wave action and to the steeper descending slope (scarp or riser) that has graded to a lower base level of erosion.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are *sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay*, and *clay*. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

Toeslope. The gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear and are constructional surfaces forming the lower part of a hillslope continuum that grades to valley or closed-depression floors.

Tread. The flat to gently sloping, topmost, laterally extensive slope of terraces, flood-plain steps, or other stepped landforms; commonly a recurring part of a series of natural steplike landforms, such as successive stream terraces.

Tuff. A generic term for any consolidated or cemented deposit that is 50 percent volcanic ash (less than 2 millimeters in size). Various types of tuff are distinguished by composition: acidic tuff is predominantly composed of acidic particles and basic tuff is predominantly composed of basic particles.

Upland. An informal, general term for the higher ground of a region, in contrast with a low-lying adjacent area, such as a valley or plain, or for land at a higher elevation than the flood plain or low stream terrace.

Volcanic breccia. A volcanoclastic rock composed mostly of angular rock fragments larger than 2 millimeters. This term is not synonymous with pyroclastic breccia as volcanic breccia forms in different ways.

Volcanic cone. A conical hill of lava and/or pyroclastics that is built up around a volcanic vent.

Volcanic dome. A steep-sided, rounded extrusion of highly viscous lava squeezed out from a volcano and forming a dome-shaped or bulbous mass of congealed lava above and around the volcanic vent.

Volcanic field. A more or less well defined area that is covered with volcanic rocks of much more diverse lithology and distribution than a lava field or that is so modified by age and erosion that its original topographic configuration, composition, and extent are uncertain.

Volcanoclastic. Pertaining to the entire spectrum of fragmental materials with a preponderance of clasts of volcanic origin. The term includes not only pyroclastic materials but also epiclastic deposits derived from volcanic source areas by normal processes of mass movement and stream erosion. Examples are welded tuff and volcanic breccia.

Weathering. All physical disintegration, chemical decomposition, and biologically induced changes in rocks or other deposits at or near the earth's surface by atmospheric or biologic agents or by circulating surface waters but involving essentially no transport of the altered material.

Well graded. Refers to soil material consisting of coarse grained particles that are well distributed over a wide range in size or diameter. Such soil normally can be easily increased in density and bearing properties by compaction. Contrasts with poorly graded soil.

Tables

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 1.—Temperature and Precipitation

(Recorded in the period 1969-2013 at Sunset Crater Volcano National Monument, Arizona)

Month	Temperature (degrees C)						Precipitation (centimeters)				
	Average daily maximum	Average daily minimum	Average daily	2 years in 10 will have--		Average number of growing degree days*	Average	2 years in 10 will have--		Average number of days with 0.254 cm or more	Average snow- fall
				Maximum temp. higher than--	Minimum temp. lower than--			Less than--	More than--		
January--	6.6	-10.9	-2.2	17	-26	0	3.30	0.20	5.46	3	35.8
February--	8.1	-8.9	-0.4	17	-23	0	3.07	0.81	4.62	3	28.7
March----	11.7	-6.2	2.7	22	-19	3	3.07	0.36	5.21	3	25.6
April----	16.2	-3.3	6.5	26	-13	23	1.88	0.69	2.41	2	9.1
May-----	21.6	0.7	11.1	31	-10	123	1.73	0.25	2.82	2	1.1
June-----	27.7	4.7	16.2	35	-4	338	1.07	0.00	1.98	1	0.0
July-----	29.2	8.9	19.0	36	1	503	6.32	3.63	9.34	6	0.0
August---	27.7	8.0	17.7	33	0	429	7.59	3.28	11.94	7	0.0
September	24.1	3.8	14.0	31	-6	225	4.67	1.27	7.62	4	0.0
October--	17.9	-2.3	7.8	27	-12	36	3.45	0.84	5.11	3	3.6
November--	11.3	-7.4	1.9	22	-18	1	2.90	0.61	5.77	3	13.5
December--	6.9	-10.9	-2.0	18	-25	0	3.61	0.97	6.35	3	33.8
Yearly: Average	17.3	-2.0	7.7	---	---	---	---	---	---	---	---
Extreme	---	---	---	36	-29	---	---	---	---	---	---
Total	---	---	---	---	---	1,682	42.34	32.31	49.71	42	151.1

* A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (50 degrees F).

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 2.—Freeze Dates in Spring and Fall

(Recorded in the period 1969-2013 at Sunset Crater Volcano National Monument, Arizona)

Probability	Temperature		
	-4 degrees C or lower	-2 degrees C or lower	0 degrees C or lower
Last freezing temperature in spring:			
1 year in 10 later than--	June 14	June 27	June 30
2 years in 10 later than--	June 5	June 19	June 28
5 years in 10 later than--	May 23	June 11	June 19
First freezing temperature in fall:			
1 year in 10 earlier than--	Oct. 18	Oct. 7	Sept. 25
2 years in 10 earlier than--	Oct. 14	Oct. 5	Sept. 22
5 years in 10 earlier than-	Oct. 6	Sept. 22	Sept. 13

Table 3.—Growing Season

(Recorded in the period 1969-2013 at Sunset Crater Volcano National Monument, Arizona)

Probability	Daily minimum temperature during growing season		
	-4 degrees C or higher	-2 degrees C or higher	0 degrees C or higher
	<u>Days</u>	<u>Days</u>	<u>Days</u>
9 years in 10	105	76	52
8 years in 10	116	85	66
5 years in 10	134	104	84
2 years in 10	148	115	99
1 year in 10	159	127	102

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 4.—Soil Legend

Map unit symbol and map unit name	Components in map unit	Percent of map unit
20: Cinderhill-Blackash complex, 15 to 60 percent slopes-----	Cinderhill	75
	Blackash	25
21: Cinderhill-Kana'a complex, 3 to 15 percent slopes-----	Cinderhill	55
	Kana'a	30
	Blackash	15
22: Cinderhill-Lava flows complex, 2 to 15 percent slopes-----	Cinderhill	65
	Lava flows	15
	Kana'a	20
23: Cumulic Haplustolls extremely gravelly sandy loam, 0 to 2 percent slopes-----	Cumulic Haplustolls	100
24: Kana'a extremely gravelly sand, 1 to 3 percent slopes-----	Kana'a	90
	Cinderhill	10
25: Kana'a-Cinder land complex, 1 to 15 percent slopes-----	Kana'a	80
	Cinder land	20
26: Kana'a-Cinder land complex, 15 to 60 percent slopes-----	Kana'a	65
	Cinder land	35
27: Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes-----	Lava flows	80
	Lithic Haplofibrists	20
28: Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes---	Lithic Ustorthents	40
	Blackash	35
	Lava flows	25
29: Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes-----	Sunsetcrater	95
	Ashy-skeletal Vitrandic Haplustepts	5
30: Sunsetcrater extremely gravelly loamy sand, 15 to 35 percent slopes-----	Sunsetcrater	100

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 5.-Acres, Hectares, and Proportionate Extent of the Map Units

Map symbol	Map unit name	Acres	Hectares	Percent
20	Cinderhill-Blackash complex, 15 to 60 percent slopes-----	709	287	18.5
21	Cinderhill-Kana'a complex, 3 to 15 percent slopes-----	545	221	14.2
22	Cinderhill-Lava flows complex, 2 to 15 percent slopes-----	184	75	4.8
23	Cumulic Haplustolls extremely gravelly sandy loam, 0 to 2 percent slopes-----	26	11	0.7
24	Kana'a extremely gravelly sand, 1 to 3 percent slopes-----	123	50	3.2
25	Kana'a-Cinder land complex, 1 to 15 percent slopes-----	124	50	3.2
26	Kana'a-Cinder land complex, 15 to 60 percent slopes-----	736	298	19.2
27	Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes----	605	245	15.8
28	Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes-----	371	150	9.7
29	Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes-	286	116	7.5
30	Sunsetcrater extremely gravelly loamy sand, 15 to 35 percent slopes	129	52	3.4
	Total-----	3,838	1,554	100.0

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 6.—Map Unit Component, Map Unit Symbol, and Ecosite ID

(This report displays major components and their associated map unit symbols and ecosite IDs)

Component name	Map unit symbol	Component kind	Ecosite ID
Blackash	20	series	R039XA141AZ
	28	series	R039XA142AZ
Cinderhill	20	series	R039XA141AZ
	21	series	R039XA141AZ
	22	series	R039XA143AZ
Cumulic Haplustolls	23	taxon above family	R039XA130AZ
Kana'a	21	series	R039XA141AZ
	24	series	R039XA141AZ
	25	series	R039XA143AZ
	26	series	R039XA143AZ
Lithic Haplofibrists	27	taxon above family	R039XA142AZ
Lithic Ustorthents	28	taxon above family	R039XA142AZ
Sunsetcrater	29	series	R039XA141AZ
	30	series	R039XA143AZ

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 7.-Ecological Site-Soil Correlation

(Only soils and miscellaneous land types with correlated ecological sites are shown)

Map unit symbol, percent of component in unit, and component name	Ecological site name	Ecological site type	Ecological site ID
20: 75%-Cinderhill-----	Cindery-Ashy Upland 17-22" p.z.	Rangeland	R039XA141AZ
25%-Blackash-----	Cindery-Ashy Upland 17-22" p.z.	Rangeland	R039XA141AZ
21: 55%-Cinderhill-----	Cindery-Ashy Upland 17-22" p.z.	Rangeland	R039XA141AZ
30%-Kana'a-----	Cindery-Ashy Upland 17-22" p.z.	Rangeland	R039XA141AZ
22: 65%-Cinderhill-----	Cinder Cones 17-22" p.z.	Rangeland	R039XA143AZ
23: 100%-Cumulic Haplustolls-----	Loamy Bottom 17-22" p.z.	Rangeland	R039XA130AZ
24: 90%-Kana'a-----	Cindery-Ashy Upland 17-22" p.z.	Rangeland	R039XA141AZ
25: 80%-Kana'a-----	Cinder Cones 17-22" p.z.	Rangeland	R039XA143AZ
26: 65%-Kana'a-----	Cinder Cones 17-22" p.z.	Rangeland	R039XA143AZ
27: 20%-Lithic Haplofibrists-----	Cinders-Lava Flow Upland 17-22" p.z.	Rangeland	R039XA142AZ
28: 40%-Lithic Ustorthents-----	Cinders-Lava Flow Upland 17-22" p.z.	Rangeland	R039XA142AZ
35%-Blackash-----	Cinders-Lava Flow Upland 17-22" p.z.	Rangeland	R039XA142AZ
29: 95%-Sunsetcrater-----	Cindery-Ashy Upland 17-22" p.z.	Rangeland	R039XA141AZ
30: 100%-Sunsetcrater-----	Cinder Cones 17-22" p.z.	Rangeland	R039XA143AZ

Table 8.—Climate, Landscape, Landform, Parent Material, and Ecological Site

(Miscellaneous nonsoil components are not displayed in this report. Component percents may not add up to 100. MAP is mean annual precipitation)

Map unit symbol and soil name	Percent of map unit	Slope	Elevation	MAP	Landscape	Landform	Parent material	Ecological site name and number
	Pct	Pct	Ft	In				
20: Cinderhill-----	75	15-60	6900-7500	18-22	Volcanic field	Cinder cone	Tephra derived from volcanic rock	Cindery-Ashy Upland 17-22" p.z., R039XA141AZ
Blackash-----	25	15-60	6900-7500	18-22	Volcanic field	Cinder cone	Tephra derived from volcanic rock	Cindery-Ashy Upland 17-22" p.z., R039XA141AZ
21: Cinderhill-----	55	3-15	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock	Cindery-Ashy Upland 17-22" p.z., R039XA141AZ
Kana'a-----	30	3-15	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock	Cindery-Ashy Upland 17-22" p.z., R039XA141AZ
22: Cinderhill-----	65	2-15	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock	Cinder Cones 17-22" p.z., R039XA143AZ
23: Cumulic Haplustolls	100	0-2	6500-7500	18-22	Volcanic field	Flood-plain step	Alluvium derived from volcanic and sedimentary rock	Loamy Bottom 17-22" p.z., p.z., R039XA130AZ
24: Kana'a-----	90	1-3	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock	Cindery-Ashy Upland 17-22" p.z., R039XA141AZ
25: Kana'a-----	80	1-15	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock	Cinder Cones 17-22" p.z., R039XA143AZ
26: Kana'a-----	65	15-60	6500-7500	18-22	Volcanic field	Cinder cone	Tephra derived from volcanic rock	Cinder Cones 17-22" p.z., R039XA143AZ
27: Lithic Haplofibrists----	20	2-15	6500-7500	18-22	Volcanic field	Aa lava flow	Organic material over tephra derived from volcanic rock	Cinders-Lava Flow Upland 17-22" p.z., R039XA142AZ

Table 8.—Climate, Landscape, Landform, Parent Material, and Ecological Site—Continued

Map unit symbol and soil name	Percent of map unit	Slope	Elevation	MAP	Landscape	Landform	Parent material	Ecological site name and number
	Pct	Pct	Ft	In				
28: Lithic Ustorthents-	40	2-15	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock	Cinders-Lava Flow Upland 17-22" p.z., R039XA142AZ
Blackash-----	35	2-15	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock	Cinders-Lava Flow Upland 17-22" p.z., R039XA142AZ
29: Sunsetcrater-----	95	1-15	6500-7500	18-22	Volcanic field	Lava field	Tephra derived from volcanic rock over clayey tephra derived from volcanic rock	Cindery-Ashy Upland 17-22" p.z., R039XA141AZ
30: Sunsetcrater-----	100	15-35	6500-7500	18-22	Volcanic field	Cinder cone	Tephra derived from volcanic rock over clayey tephra derived from volcanic rock	Cinder Cones 17-22" p.z., R039XA143AZ

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 9.—Rangeland Productivity and Characteristic Plant Communities

Map symbol and soil name	Ecological site (name and ID)	Total production		Characteristic plants	Composition
		Kind of year	Dry weight lb/acre		Pct
20: Cinderhill-----	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	Favorable Normal Unfavorable	125 86 25	sand bluestem ponderosa pine crispleaf buckwheat	40 30 5
Blackash-----	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	Favorable Normal Unfavorable	200 106 50	ponderosa pine Apache plume sand bluestem blue grama	50 30 15 3
21: Cinderhill-----	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	Favorable Normal Unfavorable	350 273 100	Apache plume ponderosa pine blue grama sand bluestem wax currant	45 30 10 10 5
Kana'a-----	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	Favorable Normal Unfavorable	225 125 75	Apache plume ponderosa pine rabbitbrush	60 20 5
22: Cinderhill-----	Cinder Cones 17-22" p.z. (R039XA143AZ)	Favorable Normal Unfavorable	50 20 5	buckwheat ponderosa pine rabbitbrush	80 5 5
Lava flows.					
23: Cumulic Haplustolls----	Loamy Bottom 17-22" p.z. (R039XA130AZ)	Favorable Normal Unfavorable	1250 946 800	rabbitbrush blue grama aster geranium prairie flax	60 20 5 5 5
24: Kana'a-----	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	Favorable Normal Unfavorable	400 240 110	Apache plume ponderosa pine blue grama	50 30 20
25: Kana'a-----	Cinder Cones 17-22" p.z. (R039XA143AZ)	Favorable Normal Unfavorable	50 10 0		
Cinder land.					
26: Kana'a-----	Cinder Cones 17-22" p.z. (R039XA143AZ)	Favorable Normal Unfavorable	50 10 0		
Cinder land.					

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 9.—Rangeland Productivity and Characteristic Plant Communities—Continued

Map symbol and soil name	Ecological site (name and ID)	Total production		Characteristic plants	Composition
		Kind of year	Dry weight lb/acre		
27: Lava flows.					
Lithic Haplofibrists--	Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ)	Favorable	100	Apache plume	60
		Normal	53	wax currant	40
		Unfavorable	15		
28: Lithic Ustorthents----	Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ)	Favorable	500	ponderosa pine	60
		Normal	240	Apache plume	35
		Unfavorable	80	wax currant	5
Blackash-----	Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ)	Favorable	500	ponderosa pine	50
		Normal	310	Apache plume	40
		Unfavorable	100	wax currant	10
Lava flows.					
29: Sunsetcrater----	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	Favorable	250	ponderosa pine	80
		Normal	125	Canada wildrye	10
		Unfavorable	75		
30: Sunsetcrater----	Cinder Cones 17-22" p.z. (R039XA143AZ)	Favorable	400	ponderosa pine	40
		Normal	255	rabbitbrush	30
		Unfavorable	150	muttongrass	15
				Canada wildrye	10
				penstemon	5

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 10.—Canopy Cover

(This report gives the canopy cover for the plant species associated with the map unit soil components. Canopy cover is determined by crown perimeter-vertical projection by species. Because this cover can overlap in layers by species, total cover can be greater than 100 percent. Plants listed with no percent canopy cover are less than 1 percent cover)

Map unit symbol, soil name, local phase and percent	Ecological site	Characteristic vegetation	Canopy cover
			<u>Pct</u>
20: Cinderhill - 75%	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	ponderosa pine	43
Blackash - 25%	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	ponderosa pine sand bluestem	26 10
21: Cinderhill - 55%	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	ponderosa pine Apache plume blue grama	13 8 2
Kana'a - 30%	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	ponderosa pine Apache plume blue grama	15 7 2
22: Cinderhill - 65%	Cinder Cones 17-22" p.z. (R039XA143AZ)	rabbitbrush buckwheat ponderosa pine	3 2 2
23: Cumulic Haplustolls - 100%	Loamy Bottom 17-22" p.z. (R039XA130AZ)	blue grama rabbitbrush	25 7
24: Kana'a - 90%	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	ponderosa pine Apache plume blue grama bottlebrush squirreltail	21 7 3 2
25: Kana'a - 80%	Cinder Cones 17-22" p.z. (R039XA143AZ)	ponderosa pine Apache plume	10 5
26: Kana'a - 65%	Cinder Cones 17-22" p.z. (R039XA143AZ)	ponderosa pine Apache plume	10 5
27: Lithic Haplofibrists - 20%	Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ)	Apache plume wax currant	6 2
28: Lithic Ustorthents - 40%	Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ)	Apache plume	16

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 10.—Canopy Cover—Continued

Map unit symbol, soil name, local phase and percent	Ecological site	Characteristic vegetation	Canopy cover
			<u>Pct</u>
28: Blackash - 35%--	Cinders-Lava Flow Upland 17-22" p.z. (R039XA142AZ)	ponderosa pine Apache plume threeawn	27 6 2
29: Sunsetcrater - 95%-----	Cindery-Ashy Upland 17-22" p.z. (R039XA141AZ)	ponderosa pine	38
30: Sunsetcrater - 100%-----	Cinder Cones 17-22" p.z. (R039XA143AZ)	ponderosa pine bottlebrush squirreltail muttongrass	22 2 2

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 11.—Index of Common and Scientific Plant Names and Plant Symbols

(Plants displayed occur within the National Soils Information System (NASIS) plant tables used for the soil survey area. The scientific and common names are referenced at the USDA PLANTS database: <http://plants.usda.gov/java/>)

Local common name	Scientific name	Plant symbol
Apache plume	Fallugia	FALLU
aster	Aster	ASTER
blue grama	Bouteloua gracilis	BOGR2
buckwheat	Eriogonum	ERIOG
Canada wildrye	Elymus canadensis	ELCA4
crispleaf buckwheat	Eriogonum corymbosum	ERCO14
geranium	Geranium	GERAN
muttongrass	Poa fendleriana	POFE
penstemon	Penstemon	PENST
ponderosa pine	Pinus ponderosa	PIPO
prairie flax	Linum lewisii	LILE3
rabbitbrush	Chrysothamnus	CHRY9
sand bluestem	Andropogon hallii	ANHA
wax currant	Ribes cereum	RICE

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 12.—Land Capability Classification

(Land capability classification is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time. Only the soils suitable for cultivation are listed. The classification is for nonirrigated areas)

Map unit symbol and component name	Land capability
20:	
Cinderhill-----	8c
Blackash-----	8c
21:	
Cinderhill-----	8c
Kana'a-----	8c
22:	
Cinderhill-----	8c
23:	
Cumulic Haplustolls-----	8c
24:	
Kana'a-----	8c
25:	
Kana'a-----	8c
26:	
Kana'a-----	8c
27:	
Lithic Haplofibrists-----	8c
28:	
Lithic Ustorthents-----	8c
Blackash-----	8c
29:	
Sunsetcrater-----	8c
30:	
Sunsetcrater-----	8c

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 13.--Land Management, Part I (Planting)

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Suitability for hand planting		Suitability for mechanical planting		Suitability for use of harvesting equipment	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Moderately suited Sandiness Slope	0.50 0.50	Unsuited Slope Sandiness Rock fragments	1.00 0.50 0.50	Poorly suited Slope Sandiness	1.00 0.50
Blackash-----	25	Moderately suited Slope	0.50	Unsuited Slope Rock fragments	1.00 0.50	Moderately suited Slope	0.50
21: Cinderhill-----	55	Moderately suited Sandiness Rock fragments	0.50 0.50	Poorly suited Rock fragments Sandiness Slope	0.75 0.50 0.50	Well suited	
Kana'a-----	30	Moderately suited Sandiness Rock fragments	0.50 0.50	Poorly suited Rock fragments Sandiness Slope	0.75 0.50 0.50	Moderately suited Sandiness	0.50
22: Cinderhill-----	65	Moderately suited Sandiness Rock fragments	0.50 0.50	Poorly suited Rock fragments Sandiness Slope	0.75 0.50 0.50	Moderately suited Sandiness	0.50
Lava flows-----	15	Not rated		Not rated		Not rated	
23: Cumulic Haplustolls-	100	Moderately suited Rock fragments	0.50	Poorly suited Rock fragments	0.75	Moderately suited Sandiness Dusty	0.50 0.02
24: Kana'a-----	90	Moderately suited Sandiness Rock fragments	0.50 0.50	Poorly suited Rock fragments Sandiness	0.75 0.50	Moderately suited Sandiness	0.50
25: Kana'a-----	80	Moderately suited Sandiness Rock fragments	0.50 0.50	Unsuited Rock fragments Sandiness	1.00 0.50	Moderately suited Sandiness	0.50
Cinder land-----	20	Not rated		Not rated		Not rated	
26: Kana'a-----	65	Poorly suited Rock fragments Sandiness	0.75 0.50	Unsuited Rock fragments Slope Sandiness	1.00 1.00 0.50	Moderately suited Slope Sandiness	0.50 0.50
Cinder land-----	35	Not rated		Not rated		Not rated	

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 13.--Land Management, Part I (Planting)--Continued

Map unit symbol and soil name	Pct. of map unit	Suitability for hand planting		Suitability for mechanical planting		Suitability for use of harvesting equipment	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
27: Lava flows-----	80	Not rated		Not rated		Not rated	
Lithic Haplofibrists	20	Unsuited		Unsuited		Poorly suited	
		Restrictive layer	1.00	Restrictive layer	1.00	Rock fragments Dusty	1.00 0.10
		Rock fragments	1.00	Rock fragments	1.00		
28: Lithic Ustorthents--	40	Moderately suited		Poorly suited		Poorly suited	
		Sandiness	0.50	Rock fragments	0.75	Rock fragments	1.00
		Rock fragments	0.50	Sandiness	0.50	Sandiness	0.50
Blackash-----	35	Moderately suited		Poorly suited		Poorly suited	
		Sandiness	0.50	Rock fragments	0.75	Rock fragments	1.00
		Rock fragments	0.50	Sandiness	0.50	Sandiness	0.50
Lava flows-----	25	Not rated		Not rated		Not rated	
29: Sunsetcrater-----	95	Moderately suited		Poorly suited		Moderately suited	
		Sandiness	0.50	Rock fragments	0.75	Sandiness	0.50
		Rock fragments	0.50	Sandiness	0.50		
				Slope	0.50		
30: Sunsetcrater-----	100	Moderately suited		Unsuited		Moderately suited	
		Sandiness	0.50	Rock fragments	1.00	Sandiness	0.50
		Rock fragments	0.50	Slope	1.00	Slope	0.50
				Sandiness	0.50		

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Table 13.—Land Management, Part II (Hazard of Erosion and Suitability for Roads)

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Hazard of off-road or off-trail erosion		Hazard of erosion on roads and trails		Suitability for roads (natural surface)	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Very severe Slope/erodibility	0.95	Severe Slope/erodibility	0.95	Poorly suited Slope Sandiness	1.00 0.50
Blackash-----	25	Moderate Slope/erodibility	0.50	Severe Slope/erodibility	0.95	Poorly suited Slope	1.00
21: Cinderhill-----	55	Slight		Moderate Slope/erodibility	0.50	Poorly suited Slope	1.00
Kana'a-----	30	Slight		Moderate Slope/erodibility	0.50	Moderately suited Slope Sandiness	0.50 0.50
22: Cinderhill-----	65	Slight		Moderate Slope/erodibility	0.50	Moderately suited Slope Sandiness	0.50 0.50
Lava flows-----	15	Not rated		Not rated		Not rated	
23: Cumulic Haplustolls-	100	Slight		Slight		Moderately suited Sandiness Dusty	0.50 0.02
24: Kana'a-----	90	Slight		Slight		Moderately suited Sandiness	0.50
25: Kana'a-----	80	Slight		Slight		Moderately suited Sandiness	0.50
Cinder land-----	20	Not rated		Not rated		Not rated	
26: Kana'a-----	65	Moderate Slope/erodibility	0.50	Severe Slope/erodibility	0.95	Poorly suited Slope Sandiness	1.00 0.50
Cinder land-----	35	Not rated		Not rated		Not rated	
27: Lava flows-----	80	Not rated		Not rated		Not rated	
Lithic Haplofibrists	20	Slight		Slight		Poorly suited Rock fragments Dusty	1.00 0.10

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 13.—Land Management, Part II (Hazard of Erosion and Suitability for Roads)—Continued

Map unit symbol and soil name	Pct. of map unit	Hazard of off-road or off-trail erosion	Value	Hazard of erosion on roads and trails	Value	Suitability for roads (natural surface)	Value
		Rating class and limiting features		Rating class and limiting features		Rating class and limiting features	
28: Lithic Ustorthents--	40	Slight		Slight		Poorly suited Rock fragments Sandiness	1.00 0.50
Blackash-----	35	Slight		Slight		Poorly suited Rock fragments Sandiness	1.00 0.50
Lava flows-----	25	Not rated		Not rated		Not rated	
29: Sunsetcrater-----	95	Slight		Moderate Slope/erodibility	0.50	Moderately suited Sandiness	0.50
30: Sunsetcrater-----	100	Moderate Slope/erodibility	0.50	Severe Slope/erodibility	0.95	Poorly suited Slope Sandiness	1.00 0.50

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Table 13.—Land Management, Part III (Site Preparation)

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Suitability for mechanical site preparation (deep)		Suitability for mechanical site preparation (surface)	
		Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Unsuited Slope	1.00	Unsuited Slope	1.00
Blackash-----	25	Poorly suited Slope	0.50	Poorly suited Slope	0.50
21: Cinderhill-----	55	Well suited		Poorly suited Rock fragments	0.50
Kana'a-----	30	Well suited		Poorly suited Rock fragments	0.50
22: Cinderhill-----	65	Well suited		Poorly suited Rock fragments	0.50
Lava flows-----	15	Not rated		Not rated	
23: Cumulic Haplustolls----	100	Well suited		Poorly suited Rock fragments	0.50
24: Kana'a-----	90	Well suited		Poorly suited Rock fragments	0.50
25: Kana'a-----	80	Well suited		Poorly suited Rock fragments	0.50
Cinder land-----	20	Not rated		Not rated	
26: Kana'a-----	65	Poorly suited Slope	0.50	Poorly suited Slope Rock fragments	0.50 0.50
Cinder land-----	35	Not rated		Not rated	
27: Lava flows-----	80	Not rated		Not rated	
Lithic Haplofibrists----	20	Unsuited Restrictive layer Rock fragments	1.00 1.00	Unsuited Restrictive layer Rock fragments	1.00 1.00
28: Lithic Ustorthents-----	40	Unsuited Restrictive layer Rock fragments	1.00 0.50	Unsuited Rock fragments	1.00

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 13.—Land Management, Part III (Site Preparation)—Continued

Map unit symbol and soil name	Pct. of map unit	Suitability for mechanical site preparation (deep)	Value	Suitability for mechanical site preparation (surface)	Value
		Rating class and limiting features		Rating class and limiting features	
28: Blackash-----	35	Poorly suited Rock fragments	0.50	Unsuited Rock fragments	1.00
Lava flows-----	25	Not rated		Not rated	
29: Sunsetcrater-----	95	Well suited		Poorly suited Rock fragments	0.50
30: Sunsetcrater-----	100	Poorly suited Slope	0.50	Poorly suited Slope Rock fragments	0.50 0.50

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Table 13.--Land Management, Part IV (Site Restoration)

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Potential for damage to soil by fire		Potential for seedling mortality	
		Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	High Texture/slope/ surface layer thickness	1.00	Moderate Available water	0.50
Blackash-----	25	High Texture/slope/ surface layer thickness	1.00	Moderate Available water	0.50
21: Cinderhill-----	55	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
Kana'a-----	30	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
22: Cinderhill-----	65	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
Lava flows-----	15	Not rated		Not rated	
23: Cumulic Haplustolls-	100	Low		High Available water	1.00
24: Kana'a-----	90	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
25: Kana'a-----	80	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
Cinder land-----	20	Not rated		Not rated	

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 13.—Land Management, Part IV (Site Restoration)—Continued

Map unit symbol and soil name	Pct. of map unit	Potential for damage to soil by fire	Value	Potential for seedling mortality	Value
		Rating class and limiting features		Rating class and limiting features	
26: Kana'a-----	65	High Texture/slope/ surface layer thickness	1.00	Moderate Available water	0.50
Cinder land-----	35	Not rated		Not rated	
27: Lava flows-----	80	Not rated		Not rated	
Lithic Haplofibrists	20	Low		High Available water	1.00
28: Lithic Ustorthents--	40	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
Blackash-----	35	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
Lava flows-----	25	Not rated		Not rated	
29: Sunsetcrater-----	95	High Texture/surface layer thickness/rock fragments	1.00	High Available water	1.00
30: Sunsetcrater-----	100	High Texture/slope/ surface layer thickness	1.00	Moderate Available water	0.50

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Table 14.—Recreation, Part I (Camp and Picnic Areas)

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Camp areas		Picnic areas	
		Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Very limited Slope Too sandy Gravel content	 1.00 1.00 1.00	Very limited Too sandy Slope Gravel content	 1.00 1.00 1.00
Blackash-----	25	Very limited Slope Too sandy Gravel content	 1.00 1.00 0.01	Very limited Too sandy Slope Gravel content	 1.00 1.00 0.01
21: Cinderhill-----	55	Somewhat limited Gravel content Slope Too sandy	 0.99 0.96 0.30	Somewhat limited Gravel content Slope Too sandy	 0.99 0.96 0.30
Kana'a-----	30	Very limited Gravel content Too sandy	 1.00 1.00	Very limited Too sandy Gravel content	 1.00 1.00
22: Cinderhill-----	65	Very limited Too sandy Gravel content	 1.00 0.88	Very limited Too sandy Gravel content	 1.00 0.88
Lava flows-----	15	Not rated		Not rated	
23: Cumulic Haplustolls-	100	Very limited Flooding Gravel content Dusty	 1.00 1.00 0.02	Very limited Gravel content Dusty	 1.00 0.02
24: Kana'a-----	90	Very limited Gravel content Too sandy	 1.00 1.00	Very limited Too sandy Gravel content	 1.00 1.00
25: Kana'a-----	80	Very limited Gravel content Too sandy	 1.00 1.00	Very limited Too sandy Gravel content	 1.00 1.00
Cinder land-----	20	Not rated		Not rated	
26: Kana'a-----	65	Very limited Slope Gravel content Too sandy	 1.00 1.00 1.00	Very limited Too sandy Slope Gravel content	 1.00 1.00 1.00
Cinder land-----	35	Not rated		Not rated	

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 14.—Recreation, Part I (Camp and Picnic Areas)—Continued

Map unit symbol and soil name	Pct. of map unit	Camp areas		Picnic areas	
		Rating class and limiting features	Value	Rating class and limiting features	Value
27: Lava flows-----	80	Not rated		Not rated	
Lithic Haplofibrists	20	Not rated		Not rated	
28: Lithic Ustorthents--	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00
		Large stones content	1.00	Large stones content	1.00
		Too sandy	0.81	Too sandy	0.81
		Gravel content	0.26	Gravel content	0.26
Blackash-----	35	Very limited		Very limited	
		Too sandy	1.00	Too sandy	1.00
		Large stones content	1.00	Large stones content	1.00
Lava flows-----	25	Not rated		Not rated	
29: Sunsetcrater-----	95	Very limited		Very limited	
		Gravel content	1.00	Gravel content	1.00
		Too sandy	0.30	Too sandy	0.30
30: Sunsetcrater-----	100	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Gravel content	1.00	Gravel content	1.00
		Too sandy	0.30	Too sandy	0.30

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Table 14.-Recreation, Part II (Trail Management)

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Foot traffic and equestrian trails		Mountain bike and off-road vehicle trails	
		Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Very limited Too sandy Slope	1.00 1.00	Very limited Too sandy Slope	1.00 1.00
Blackash-----	25	Very limited Too sandy Slope	1.00 1.00	Very limited Too sandy Slope	1.00 0.78
21: Cinderhill-----	55	Somewhat limited Too sandy	0.30	Somewhat limited Too sandy	0.30
Kana'a-----	30	Very limited Too sandy Gravel content	1.00 1.00	Very limited Too sandy Gravel content	1.00 1.00
22: Cinderhill-----	65	Very limited Too sandy	1.00	Very limited Too sandy	1.00
Lava flows-----	15	Not rated		Not rated	
23: Cumulic Haplustolls-	100	Very limited Gravel content Dusty	1.00 0.02	Very limited Gravel content Dusty	1.00 0.02
24: Kana'a-----	90	Very limited Too sandy Gravel content	1.00 1.00	Very limited Too sandy Gravel content	1.00 1.00
25: Kana'a-----	80	Very limited Too sandy Gravel content	1.00 1.00	Very limited Too sandy Gravel content	1.00 1.00
Cinder land-----	20	Not rated		Not rated	
26: Kana'a-----	65	Very limited Too sandy Gravel content Slope	1.00 1.00 1.00	Very limited Too sandy Gravel content Slope	1.00 1.00 0.32
Cinder land-----	35	Not rated		Not rated	
27: Lava flows-----	80	Not rated		Not rated	
Lithic Haplofibrists	20	Not rated		Not rated	

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Table 14.—Recreation, Part II (Trail Management)—Continued

Map unit symbol and soil name	Pct. of map unit	Foot traffic and equestrian trails		Mountain bike and off-road vehicle trails	
		Rating class and limiting features	Value	Rating class and limiting features	Value
28: Lithic Ustorthents--	40	Very limited Large stones content Too sandy	1.00 0.81	Very limited Large stones content Too sandy	1.00 0.81
Blackash-----	35	Very limited Too sandy Large stones content	1.00 1.00	Very limited Too sandy Large stones content	1.00 1.00
Lava flows-----	25	Not rated		Not rated	
29: Sunsetcrater-----	95	Very limited Gravel content Too sandy	1.00 0.30	Very limited Gravel content Too sandy	1.00 0.30
30: Sunsetcrater-----	100	Very limited Gravel content Slope Too sandy	1.00 1.00 0.30	Very limited Gravel content Slope Too sandy	1.00 0.56 0.30

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Table 15.-Dwellings and Small Commercial Buildings

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Very limited Slope	1.00	Very limited Slope	1.00	Very limited Slope	1.00
Blackash-----	25	Very limited Slope	1.00	Very limited Slope	1.00	Very limited Slope	1.00
21: Cinderhill-----	55	Somewhat limited Slope	0.96	Somewhat limited Slope	0.96	Very limited Slope	1.00
Kana'a-----	30	Not limited		Not limited		Somewhat limited Slope	0.50
22: Cinderhill-----	65	Not limited		Not limited		Somewhat limited Slope	0.50
Lava flows-----	15	Not rated		Not rated		Not rated	
23: Cumulic Haplustolls-	100	Very limited Flooding	1.00	Very limited Flooding	1.00	Very limited Flooding	1.00
24: Kana'a-----	90	Not limited		Not limited		Not limited	
25: Kana'a-----	80	Not limited		Not limited		Not limited	
Cinder land-----	20	Not rated		Not rated		Not rated	
26: Kana'a-----	65	Very limited Slope	1.00	Very limited Slope	1.00	Very limited Slope	1.00
Cinder land-----	35	Not rated		Not rated		Not rated	
27: Lava flows-----	80	Not rated		Not rated		Not rated	
Lithic Haplofibrists	20	Very limited Depth to hard bedrock	1.00	Very limited Depth to hard bedrock	1.00	Very limited Depth to hard bedrock	1.00
28: Lithic Ustorthents--	40	Very limited Depth to hard bedrock	1.00	Very limited Depth to hard bedrock	1.00	Very limited Depth to hard bedrock	1.00
Blackash-----	35	Not limited		Not limited		Not limited	
Lava flows-----	25	Not rated		Not rated		Not rated	

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Table 15.—Dwellings and Small Commercial Buildings—Continued

Map unit symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
29: Sunsetcrater-----	95	Not limited		Not limited		Somewhat limited Slope	0.13
30: Sunsetcrater-----	100	Very limited Slope	1.00	Very limited Slope	1.00	Very limited Slope	1.00

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Table 16.—Roads and Streets, Shallow Excavations, and Landscaping

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Local roads and streets	Value	Shallow excavations	Value	Landscaping	Value
		Rating class and limiting features		Rating class and limiting features		Rating class and limiting features	
20: Cinderhill-----	75	Very limited Slope	1.00	Very limited Slope Unstable excavation walls	1.00 1.00	Very limited Slope Too sandy Droughty Gravel content	1.00 1.00 1.00 1.00
Blackash-----	25	Very limited Slope	1.00	Very limited Slope Unstable excavation walls	1.00 1.00	Very limited Slope Too sandy Droughty Gravel content	1.00 1.00 1.00 0.01
21: Cinderhill-----	55	Somewhat limited Slope	0.96	Very limited Unstable excavation walls Slope	1.00 0.96	Very limited Droughty Gravel content Slope	1.00 0.99 0.96
Kana'a-----	30	Not limited		Very limited Unstable excavation walls	1.00	Very limited Too sandy Gravel content Droughty	1.00 1.00 1.00
22: Cinderhill-----	65	Not limited		Very limited Unstable excavation walls	1.00	Very limited Too sandy Droughty Gravel content	1.00 1.00 0.88
Lava flows-----	15	Not rated		Not rated		Not rated	
23: Cumulic Haplustolls-	100	Somewhat limited Frost action Flooding	0.50 0.40	Somewhat limited Dusty Unstable excavation walls	0.02 0.01	Very limited Gravel content Droughty Dusty	1.00 0.49 0.02
24: Kana'a-----	90	Not limited		Very limited Unstable excavation walls	1.00	Very limited Gravel content Droughty Too sandy	1.00 1.00 0.50
25: Kana'a-----	80	Not limited		Very limited Unstable excavation walls	1.00	Very limited Too sandy Gravel content Droughty	1.00 1.00 1.00
Cinder land-----	20	Not rated		Not rated		Not rated	

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Table 16.—Roads and Streets, Shallow Excavations, and Landscaping—Continued

Map unit symbol and soil name	Pct. of map unit	Local roads and streets	Value	Shallow excavations	Value	Landscaping	Value
		Rating class and limiting features		Rating class and limiting features		Rating class and limiting features	
26: Kana'a-----	65	Very limited Slope	1.00	Very limited Slope Unstable excavation walls	1.00 1.00	Very limited Slope Too sandy Gravel content Droughty	1.00 1.00 1.00 1.00
Cinder land-----	35	Not rated		Not rated		Not rated	
27: Lava flows-----	80	Not rated		Not rated		Not rated	
Lithic Haplofibrists	20	Very limited Depth to hard bedrock Frost action	1.00 0.50	Not rated		Very limited Depth to bedrock Droughty Dusty	1.00 1.00 0.10
28: Lithic Ustorthents--	40	Very limited Depth to hard bedrock	1.00	Very limited Depth to hard bedrock Unstable excavation walls	1.00 1.00	Very limited Depth to bedrock Droughty Gravel content	1.00 1.00 0.26
Blackash-----	35	Not limited		Very limited Unstable excavation walls	1.00	Very limited Droughty Too sandy	1.00 0.50
Lava flows-----	25	Not rated		Not rated		Not rated	
29: Sunsetcrater-----	95	Not limited		Somewhat limited Unstable excavation walls	0.51	Very limited Gravel content Droughty	1.00 0.99
30: Sunsetcrater-----	100	Very limited Slope	1.00	Very limited Slope Unstable excavation walls	1.00 0.42	Very limited Slope Gravel content Droughty	1.00 1.00 1.00

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Table 17.—Sewage Disposal

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Very limited Filtering capacity	1.00	Very limited Slope	1.00
		Slope	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
Blackash-----	25	Very limited Filtering capacity	1.00	Very limited Slope	1.00
		Slope	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
21: Cinderhill-----	55	Very limited Filtering capacity	1.00	Very limited Seepage	1.00
		Seepage, bottom layer	1.00	Slope	1.00
		Slope	0.96		
Kana'a-----	30	Very limited Filtering capacity	1.00	Very limited Seepage	1.00
		Seepage, bottom layer	1.00	Slope	0.92
22: Cinderhill-----	65	Very limited Filtering capacity	1.00	Very limited Seepage	1.00
		Seepage, bottom layer	1.00	Slope	0.92
Lava flows-----	15	Not rated		Not rated	
23: Cumulic Haplustolls-	100	Very limited Seepage, bottom layer	1.00	Very limited Seepage Flooding	1.00 0.40
		Slow water movement	0.50		
		Flooding	0.40		
24: Kana'a-----	90	Very limited Filtering capacity	1.00	Very limited Seepage	1.00
		Seepage, bottom layer	1.00		
25: Kana'a-----	80	Very limited Filtering capacity	1.00	Very limited Seepage	1.00
		Seepage, bottom layer	1.00		
Cinder land-----	20	Not rated		Not rated	

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 17.—Sewage Disposal—Continued

Map unit symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
26:					
Kana'a-----	65	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
Cinder land-----	35	Not rated		Not rated	
27:					
Lava flows-----	80	Not rated		Not rated	
Lithic Haplofibrists	20	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
				Slope	0.32
28:					
Lithic Ustorthents--	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
				Slope	0.08
Blackash-----	35	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
Lava flows-----	25	Not rated		Not rated	
29:					
Sunsetcrater-----	95	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slow water movement	0.50	Slope	0.68
30:					
Sunsetcrater-----	100	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Filtering capacity	1.00		

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 18.—Source of Gravel and Sand

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The ratings given for the thickest layer are for the thickest layer above and excluding the bottom layer. The numbers in the value columns range from 0.00 to 0.99. The greater the value, the greater the likelihood that the bottom layer or thickest layer of the soil is a source of sand or gravel. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Gravel source		Sand source	
		Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.61
		Thickest layer	0.00	Thickest layer	0.93
Blackash-----	25	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.50
		Thickest layer	0.00	Thickest layer	0.74
21: Cinderhill-----	55	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.58
		Thickest layer	0.00	Thickest layer	0.93
Kana'a-----	30	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.58
		Thickest layer	0.00	Thickest layer	0.96
22: Cinderhill-----	65	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.61
		Thickest layer	0.00	Thickest layer	0.96
Lava flows-----	15	Not rated		Not rated	
23: Cumulic Haplustolls-	100	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.10
		Thickest layer	0.00	Thickest layer	0.10
24: Kana'a-----	90	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.66
		Thickest layer	0.00	Thickest layer	0.98
25: Kana'a-----	80	Fair		Fair	
		Thickest layer	0.00	Bottom layer	0.69
		Bottom layer	0.28	Thickest layer	0.98
Cinder land-----	20	Not rated		Not rated	
26: Kana'a-----	65	Fair		Fair	
		Thickest layer	0.00	Bottom layer	0.72
		Bottom layer	0.35	Thickest layer	0.99
Cinder land-----	35	Not rated		Not rated	

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 18.—Source of Gravel and Sand—Continued

Map unit symbol and soil name	Pct. of map unit	Gravel source		Sand source	
		Rating class and limiting features	Value	Rating class and limiting features	Value
27:					
Lava flows-----	80	Not rated		Not rated	
Lithic Haplofibrists	20	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
28:					
Lithic Ustorthents--	40	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.51
		Thickest layer	0.00	Thickest layer	0.90
Blackash-----	35	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.65
		Thickest layer	0.00	Thickest layer	0.99
Lava flows-----	25	Not rated		Not rated	
29:					
Sunsetcrater-----	95	Fair		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.13	Thickest layer	0.10
30:					
Sunsetcrater-----	100	Fair		Fair	
		Thickest layer	0.00	Bottom layer	0.10
		Bottom layer	0.18	Thickest layer	0.20

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 19.—Source of Reclamation Material, Roadfill, and Topsoil

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.00 to 0.99. The smaller the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Source of reclamation material		Roadfill source		Topsoil source	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Poor		Poor		Poor	
		Too sandy	0.00	Slope	0.00	Rock fragments	0.00
		Wind erosion	0.00			Slope	0.00
		Droughty	0.00			Too sandy	0.00
Blackash-----	25	Poor		Poor		Poor	
		Too sandy	0.00	Slope	0.00	Slope	0.00
		Wind erosion	0.00			Too sandy	0.00
		Droughty	0.00			Rock fragments	0.13
21: Cinderhill-----	55	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Droughty	0.00			Rock fragments	0.00
		Low content of organic matter	0.68			Slope	0.04
Kana'a-----	30	Poor		Good		Poor	
		Too sandy	0.00			Hard to reclaim	0.00
		Droughty	0.00			(rock fragments)	
		Low content of organic matter	0.68			Rock fragments	0.00
						Too sandy	0.00
22: Cinderhill-----	65	Poor		Good		Poor	
		Too sandy	0.00			Rock fragments	0.00
		Wind erosion	0.00			Too sandy	0.00
		Droughty	0.00			Hard to reclaim	0.00
						(rock fragments)	
Lava flows-----	15	Not rated		Not rated		Not rated	
23: Cumulic Haplustolls-	100	Fair		Good		Poor	
		Droughty	0.15			Rock fragments	0.00
		Low content of organic matter	0.68			Hard to reclaim	0.38
						(rock fragments)	
						Exchange capacity	0.86
24: Kana'a-----	90	Poor		Good		Poor	
		Too sandy	0.00			Hard to reclaim	0.00
		Droughty	0.00			(rock fragments)	
		Low content of organic matter	0.68			Rock fragments	0.00
						Too sandy	0.00
25: Kana'a-----	80	Poor		Good		Poor	
		Too sandy	0.00			Hard to reclaim	0.00
		Droughty	0.00			(rock fragments)	
		Low content of organic matter	0.68			Rock fragments	0.00
						Too sandy	0.00
Cinder land-----	20	Not rated		Not rated		Not rated	

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 19.—Source of Reclamation Material, Roadfill, and Topsoil—Continued

Map unit symbol and soil name	Pct. of map unit	Source of reclamation material		Roadfill source		Topsoil source	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
26:							
Kana'a-----	65	Poor		Poor		Poor	
		Too sandy	0.00	Slope	0.00	Hard to reclaim	0.00
		Droughty	0.00			(rock fragments)	
		Low content of organic matter	0.68			Rock fragments	0.00
						Slope	0.00
Cinder land-----	35	Not rated		Not rated		Not rated	
27:							
Lava flows-----	80	Not rated		Not rated		Not rated	
Lithic Haplofibrists	20	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Dusty	0.79	Exchange capacity	0.06
28:							
Lithic Ustorthents--	40	Poor		Poor		Poor	
		Too sandy	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Droughty	0.00			Too sandy	0.00
		Depth to bedrock	0.00			Rock fragments	0.00
Blackash-----	35	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Wind erosion	0.00			Rock fragments	0.01
		Droughty	0.00			Exchange capacity	0.28
Lava flows-----	25	Not rated		Not rated		Not rated	
29:							
Sunsetcrater-----	95	Fair		Good		Poor	
		Droughty	0.03			Rock fragments	0.00
		Low content of organic matter	0.68			Hard to reclaim	0.00
		Too sandy	0.87			(rock fragments)	
						Exchange capacity	0.34
30:							
Sunsetcrater-----	100	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Hard to reclaim	0.00
		Too sandy	0.54			(rock fragments)	
		Low content of organic matter	0.68			Rock fragments	0.00
						Slope	0.00

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 20.—Ponds and Embankments

(Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table)

Map unit symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
20: Cinderhill-----	75	Very limited Seepage Slope	1.00 1.00	Very limited Seepage	1.00	Very limited Depth to water	1.00
Blackash-----	25	Very limited Seepage Slope	1.00 1.00	Very limited Seepage	1.00	Very limited Depth to water	1.00
21: Cinderhill-----	55	Very limited Seepage Slope	1.00 1.00	Very limited Seepage	1.00	Very limited Depth to water	1.00
Kana'a-----	30	Very limited Seepage Slope	1.00 0.68	Very limited Seepage Piping	1.00 1.00	Very limited Depth to water	1.00
22: Cinderhill-----	65	Very limited Seepage Slope	1.00 0.68	Very limited Seepage	1.00	Very limited Depth to water	1.00
Lava flows-----	15	Not rated		Not rated		Not rated	
23: Cumulic Haplustolls-	100	Very limited Seepage	1.00	Somewhat limited Seepage Dusty	0.57 0.02	Very limited Depth to water	1.00
24: Kana'a-----	90	Very limited Seepage	1.00	Very limited Seepage Piping	1.00 1.00	Very limited Depth to water	1.00
25: Kana'a-----	80	Very limited Seepage	1.00	Very limited Seepage	1.00	Very limited Depth to water	1.00
Cinder land-----	20	Not rated		Not rated		Not rated	
26: Kana'a-----	65	Very limited Seepage Slope	1.00 1.00	Very limited Seepage	1.00	Very limited Depth to water	1.00
Cinder land-----	35	Not rated		Not rated		Not rated	
27: Lava flows-----	80	Not rated		Not rated		Not rated	
Lithic Haplofibrists	20	Very limited Depth to bedrock Slope	1.00 0.08	Very limited Seepage Thin layer Hard to pack Dusty	1.00 1.00 1.00 0.10	Very limited Depth to water	1.00

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 20.—Ponds and Embankments—Continued

Map unit symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
28: Lithic Ustorthents--	40	Very limited Depth to bedrock	1.00	Very limited Seepage Thin layer	1.00 1.00	Very limited Depth to water	1.00
Blackash-----	35	Very limited Seepage	1.00	Very limited Seepage	1.00	Very limited Depth to water	1.00
Lava flows-----	25	Not rated		Not rated		Not rated	
29: Sunsetcrater-----	95	Very limited Seepage Slope	1.00 0.32	Very limited Seepage	1.00	Very limited Depth to water	1.00
30: Sunsetcrater-----	100	Very limited Seepage Slope	1.00 1.00	Very limited Seepage	1.00	Very limited Depth to water	1.00

Table 21.--Engineering Properties

(Absence of an entry indicates that data were not estimated)

Map unit symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plas- ticity index
			Unified	AASHTO	>750 mm	75-250 mm	4	10	40	200		
					Pct	Pct						
20: Cinderhill-----	<u>Cm</u>											
	0-8	Very gravelly coarse sand	SW-SM	A-1-a	0	0	75-80	45-55	20-30	4-10	0-22	NP-4
	8-18	Extremely gravelly loamy sand, very gravelly loamy sand	SM	A-1-b	0	0	65-75	35-55	25-45	10-20	0-24	NP-6
	18-38	Extremely gravelly sand, very gravelly sand	SP-SM	A-1-b	0	0	70-80	35-55	25-45	2-10	0-22	NP-4
	38-152	Extremely gravelly coarse sand, very gravelly coarse sand	SW-SM	A-1-a	0	0	65-75	35-55	15-30	3-10	0-22	NP-4
Blackash-----	0-5	Gravelly coarse sand	SW-SM	A-1-b	0	0	95-96	71-81	32-42	7-14	0-22	NP-4
	5-18	Very gravelly loamy sand, gravelly loamy sand	SM	A-2-4	0	0	90-96	66-81	51-69	18-29	0-24	NP-6
	18-41	Gravelly loamy coarse sand, very gravelly loamy coarse sand	SM	A-1-b	0	0	95-96	66-76	38-50	16-25	0-24	NP-6
	41-152	Very gravelly coarse sand, gravelly coarse sand	SW-SM	A-1-b	0	0	86-96	63-81	28-42	7-14	0-22	NP-4
21: Cinderhill-----	0-5	Very gravelly loamy sand	SM	A-1-b	0	0	80-90	40-65	30-55	10-25	0-24	NP-6
	5-15	Very gravelly loamy sand, gravelly loamy sand	SC-SM	A-2-4	0	0	80-90	55-80	45-65	10-20	0-24	NP-6
	15-30	Very gravelly coarse sand	SW-SM	A-1-b	0	0	80-90	40-65	20-35	5-10	0-20	NP-3
	30-152	Gravelly coarse sand, very gravelly coarse sand	SP-SM	A-1-b	0	0	80-90	50-80	25-40	5-15	0-20	NP-3
Kana'a-----	0-8	Extremely gravelly coarse sand	SP	A-1-a	0	0	60-70	20-40	10-20	2-5	0-19	NP-2
	8-20	Very gravelly coarse sand	SP-SM	A-1-b	0	0	80-90	40-65	20-35	3-10	0-22	NP-4
	20-28	Extremely gravelly coarse sand	SW-SM	A-1-a	0	0	65-80	20-50	10-25	2-10	0-22	NP-4
	28-152	Extremely gravelly coarse sand	SP	A-1-a	0	0	55-70	10-35	5-20	1-5	0-19	NP-2

Table 21.—Engineering Properties—Continued

Map unit symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plas- ticity index
			Unified	AASHTO	>750 mm	75-250 mm	4	10	40	200		
	Cm				Pct	Pct					Pct	
22:												
Cinderhill-----	0-5	Very gravelly coarse sand	SW-SM	A-1-b	0	0	80-90	40-65	20-35	4-10	0-20	NP-3
	5-18	Extremely gravelly sand	SW	A-1-a	0	0	65-85	25-55	20-45	2-6	0-20	NP-3
	18-152	Very gravelly coarse sand	SW-SM	A-1-a	0	0	75-85	40-65	20-35	3-8	0-20	NP-3
Lava flows.												
23:												
Cumulic												
Haplustolls----	0-5	Very gravelly sandy loam, extremely gravelly sandy loam	GP-GC	A-2-4	0	0	40-60	20-45	15-35	5-20	23-32	6-10
	5-20	Very gravelly sandy loam, extremely gravelly sandy loam	GP-GC	A-2-4	0	0	45-60	20-45	15-35	5-20	23-32	6-10
	20-38	Sandy loam	SC	A-2-4	0	0	90-100	75-90	55-70	30-40	21-29	6-10
	38-69	Gravelly loam	SC	A-4	0	0	70-85	50-75	40-65	30-50	23-30	7-12
	69-140	Gravelly loamy sand	SC-SM	A-2-4	0	0	80-95	55-80	40-65	10-20	18-25	3-7
	140-152	Very gravelly loamy sand	SP-SC	A-1-b	0	0	60-80	35-65	30-55	5-20	18-25	3-7
24:												
Kana'a-----	0-5	Extremely gravelly sand	SP	A-1-a	0	0	60-70	20-40	15-30	1-5	0-20	NP-3
	5-10	Extremely gravelly sand	SP	A-1-a	0	0	60-75	20-45	15-35	1-5	0-20	NP-3
	10-20	Extremely gravelly coarse sand	GP	A-1-a	0	0	40-60	10-35	5-15	1-5	0-19	NP-1
	20-48	Extremely gravelly coarse sand	SW	A-1-a	0	0	60-80	20-45	10-20	2-5	0-19	NP-1
	48-152	Extremely gravelly coarse sand	SP	A-1-a	0	0	60-70	20-40	5-20	2-5	0-19	NP-1
25:												
Kana'a-----	0-5	Extremely gravelly coarse sand	GP	A-1-a	0	0	35-55	15-35	5-20	1-5	0-20	NP-3
	5-10	Very gravelly coarse sand	SP-SM	A-1-b	0	0	80-85	45-65	20-35	5-10	0-20	NP-3
	10-152	Extremely gravelly coarse sand	GP	A-1-a	0	0	35-55	15-35	5-20	1-5	0-20	NP-3
Cinder land.												

Table 21.—Engineering Properties—Continued

Map unit symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plas- ticity index
			Unified	AASHTO	>750 mm	75-250 mm	4	10	40	200		
	Cm				Pct	Pct					Pct	
26: Kana'a-----	0-8	Extremely gravelly coarse sand	SW	A-1-a	0	0	50-65	15-40	10-20	2-5	0-19	NP-2
	8-15	Extremely gravelly loamy sand	GW-GM	A-1-a	0	0	30-45	15-40	15-35	5-15	0-24	NP-6
	15-152	Gravel	GW	A-1-a	0	0	30-40	10-20	5-15	1-2	0-19	NP-2
Cinder land.												
27: Lava flows.												
Lithic Haplofibrists--	0-8	Slightly decomposed plant material			0	0	100	100	100	100	---	---
	8-10	Very gravelly loam	SC	A-6	0-10	0-10	70-85	50-85	45-75	30-60	30-38	12-18
	10-35	Bedrock	---	---	---	---	---	---	---	---	---	---
28: Lithic Ustorthents----	0-5	Very gravelly loamy sand	SC-SM	A-2-4	0	0	85-100	55-75	40-60	10-20	0-24	NP-6
	5-11	Gravelly sand	SP-SM	A-2-4	0	0	85-95	65-85	50-70	5-10	0-20	NP-3
	11-36	Very gravelly coarse sand	SW-SM	A-1-b	0	0	80-95	40-70	20-35	5-10	0-20	NP-3
	36-61	Bedrock	---	---	---	---	---	---	---	---	---	---
Blackash-----	0-8	Gravelly sand	SP-SM	A-2-4	0	0	91-95	68-86	50-67	4-10	0-20	NP-3
	8-23	Gravelly coarse sand	SW-SM	A-1-b	0	0	91-100	69-86	31-43	7-13	0-20	NP-3
	23-41	Very gravelly coarse sand, extremely gravelly coarse sand	SP-SM	A-1-a	0	0	51-81	31-71	14-35	3-11	0-20	NP-3
	41-152	Gravelly sand	SP-SM	A-2-4	0	0	87-95	65-86	48-67	4-10	0-20	NP-3
Lava flows.												
29: Sunsetcrater----	0-5	Extremely gravelly loamy sand	GW-GM	A-1-a	0	0	50-55	15-35	10-30	5-15	0-24	NP-6
	5-20	Extremely gravelly loamy coarse sand	SP-SC	A-1-a	0	0	50-70	15-45	5-25	2-10	0-24	NP-6
	20-46	Extremely gravelly coarse sand	SP	A-1-a	0	0	50-55	10-35	5-20	1-5	0-19	NP-1
	46-81	Extremely gravelly sandy loam, extremely gravelly sandy clay loam	GP-GC	A-2-6	0	0	40-55	15-40	10-35	5-20	30-38	12-18
	81-152	Very gravelly sandy loam	SC	A-2-4	0	0	60-75	40-65	30-50	15-30	23-30	7-12

Table 21.—Engineering Properties—Continued

Map unit symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plas- ticity index
			Unified	AASHTO	>750 mm	75-250 mm	4	10	40	200		
	<u>Cm</u>				<u>Pct</u>	<u>Pct</u>					<u>Pct</u>	
30: Sunsetcrater----	0-5	Extremely gravelly loamy sand	GW-GM	A-1-a	0	0	35-50	15-40	10-35	5-15	0-24	NP-6
	5-18	Very gravelly loamy sand, extremely gravelly loamy sand	SP-SC	A-1-a	0	0	45-65	20-55	15-45	5-15	0-24	NP-6
	18-30	Extremely gravelly coarse sand	GP	A-1-a	0	0	35-50	10-40	5-20	1-5	0-20	NP-3
	30-53	Very gravelly sandy clay loam	GC	A-2-6	0	0	60-75	40-65	35-65	25-45	32-42	13-21
	53-152	Extremely gravelly loamy sand	GW	A-1-a	0	0	40-50	15-40	10-35	2-10	0-24	NP-6

Table 22.—Physical Soil Properties

(Values for sand, silt, and clay are shown either as a range or as a representative value. Absence of an entry indicates that data were not estimated)

Map unit symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Shrink- swell potential	Organic matter
	In	Pct	Pct	Pct	g/cc	In/hr	In/in	Pct	Pct
20:									
Cinderhill-----	0-3	92	4	1-8	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	3-7	78	16	2-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
	7-15	94	1	1-8	1.45-1.60	20.0-99.9	0.03-0.04	0.0-2.9	0.5-0.8
	15-60	91	4	1-8	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
Blackash-----	0-2	91	6	1-8	1.45-1.60	20.0-99.9	0.02-0.05	0.0-2.9	0.5-0.8
	2-7	79	17	2-10	1.45-1.60	5.9-20.0	0.04-0.05	0.0-2.9	0.5-0.8
	7-16	78	18	2-10	1.45-1.60	5.9-20.0	0.03-0.05	0.0-2.9	0.5-0.8
	16-60	91	6	1-8	1.45-1.60	20.0-99.9	0.02-0.05	0.0-2.9	0.5-0.8
21:									
Cinderhill-----	0-2	78	16	3-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
	2-6	84	9	3-10	1.45-1.60	5.9-20.0	0.03-0.05	0.0-2.9	0.5-0.8
	6-12	91	6	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	12-60	92	6	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
Kana'a-----	0-3	91	6	1-5	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	3-8	90	4	1-8	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	8-11	91	4	1-8	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	11-60	92	6	1-5	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
22:									
Cinderhill-----	0-2	91	6	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	2-7	94	1	1-6	1.45-1.60	20.0-99.9	0.03-0.04	0.0-2.9	0.5-0.8
	7-60	91	4	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
23:									
Cumulic									
Haplustolls----	0-2	68	20	10-16	1.35-1.50	2.0-5.9	0.04-0.07	0.0-2.9	1.5-2.5
	2-8	68	20	10-16	1.35-1.50	2.0-5.9	0.04-0.07	0.0-2.9	1.5-2.5
	8-15	67	19	10-16	1.35-1.50	2.0-5.9	0.07-0.12	0.0-2.9	0.5-0.8
	15-27	44	40	12-18	1.25-1.40	0.6-2.0	0.10-0.14	0.0-2.9	0.5-0.8
	27-55	81	9	6-12	1.45-1.60	5.9-20.0	0.04-0.05	0.0-2.9	0.5-0.8
	55-60	81	9	6-12	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
24:									
Kana'a-----	0-2	95	1	2-6	1.45-1.60	20.0-99.9	0.03-0.04	0.0-2.9	0.5-0.8
	2-4	95	1	2-6	1.45-1.60	20.0-99.9	0.03-0.04	0.0-2.9	0.5-0.8
	4-8	92	6	1-4	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	8-19	92	6	1-4	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	19-60	92	6	1-4	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8

Table 22.—Physical Soil Properties—Continued

Map unit symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Shrink- swell potential	Organic matter
	In	Pct	Pct	Pct	g/cc	In/hr	In/in	Pct	Pct
25:									
Kana'a-----	0-2	92	4	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	2-4	92	4	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	4-60	92	4	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
26:									
Kana'a-----	0-3	91	6	1-5	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	3-6	78	16	2-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
	6-60	95	1	1-5	1.45-1.60	20.0-99.9	0.00-0.01	0.0-2.9	0.5-0.8
27:									
Lithic									
Haplofibrists--	0-3	0	0	0-0	0.25-0.75	5.9-99.9	0.00-0.04	---	2.0-8.0
	3-4	42	38	18-25	1.25-1.40	0.6-2.0	0.08-0.11	3.0-5.9	0.5-0.8
	4-14	---	---	---	---	0.0-0.1	---	---	---
28:									
Lithic									
Ustorthents----	0-2	84	9	2-10	1.45-1.60	5.9-20.0	0.03-0.05	0.0-2.9	0.5-0.8
	2-4	92	2	1-6	1.45-1.60	20.0-99.9	0.04-0.06	0.0-2.9	0.5-0.8
	4-14	91	6	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	14-24	---	---	---	---	0.0-0.1	---	---	---
Blackash-----	0-3	94	1	1-6	1.45-1.60	20.0-99.9	0.04-0.06	0.0-2.9	0.5-0.8
	3-9	91	6	1-6	1.45-1.60	20.0-99.9	0.03-0.06	0.0-2.9	0.5-0.8
	9-16	91	6	1-6	1.45-1.60	20.0-99.9	0.03-0.04	0.0-2.9	0.5-0.8
	16-60	94	1	1-6	1.45-1.60	20.0-99.9	0.04-0.06	0.0-2.9	0.5-0.8
29:									
Sunsetcrater----	0-2	78	16	3-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
	2-8	82	10	3-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
	8-18	92	6	1-4	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	18-32	61	19	18-25	1.25-1.40	0.6-2.0	0.07-0.10	3.0-5.9	0.5-0.8
	32-60	65	19	12-18	1.35-1.50	2.0-5.9	0.04-0.07	0.0-2.9	0.5-0.8
30:									
Sunsetcrater----	0-2	78	16	2-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
	2-7	84	9	2-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8
	7-12	91	4	1-6	1.45-1.60	20.0-99.9	0.02-0.04	0.0-2.9	0.5-0.8
	12-21	54	20	20-30	1.25-1.40	0.6-2.0	0.08-0.10	3.0-5.9	0.5-0.8
	21-60	83	9	2-10	1.45-1.60	5.9-20.0	0.03-0.04	0.0-2.9	0.5-0.8

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Table 23.—Erosion Properties

(Entries under "Erosion factors" apply to the entire profile. Entries under "Wind erodibility group" and "Wind erodibility index" apply only to the surface layer)

Map unit symbol and soil name	Depth (cm)	Erosion factors			Wind erodi- bility group	Wind erodi- bility index
		Kw	Kf	T		
20:						
Cinderhill-----	0-8	.02	.02	5	2	134
	8-18	.05	.17			
	18-38	.02	.02			
	38-152	.02	.02			
Blackash-----	0-5	.02	.02	5	1	160
	5-18	.10	.17			
	18-41	.05	.15			
	41-152	.02	.02			
21:						
Cinderhill-----	0-5	.05	.15	5	3	86
	5-15	.05	.10			
	15-30	.02	.02			
	30-152	.02	.02			
Kana'a-----	0-8	.02	.02	5	5	56
	8-20	.02	.02			
	20-28	.02	.02			
	28-152	.02	.02			
22:						
Cinderhill-----	0-5	.02	.02	5	2	134
	5-18	.02	.02			
	18-152	.02	.02			
Lava flows.						
23:						
Cumulic Haplustolls---	0-5	.05	.17	3	8	0
	5-20	.05	.17			
	20-38	.24	.24			
	38-69	.24	.43			
	69-140	.10	.15			
	140-152	.05	.15			
24:						
Kana'a-----	0-5	.02	.02	5	5	56
	5-10	.02	.02			
	10-20	.02	.02			
	20-48	.02	.02			
	48-152	.02	.02			
25:						
Kana'a-----	0-5	.02	.02	5	5	56
	5-10	.02	.02			
	10-152	.02	.02			
Cinder land.						
26:						
Kana'a-----	0-8	.02	.02	1	5	56
	8-15	.02	.15			
	15-152	.02	.02			
Cinder land.						

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 23.—Erosion Properties—Continued

Map unit symbol and soil name	Depth (cm)	Erosion factors			Wind erodi- bility group	Wind erodi- bility index
		Kw	Kf	T		
27: Lava flows.						
Lithic Haplofibrists--	0-8	---	---	1	8	0
	8-10	.15	.37			
	10-35	---	---			
28: Lithic Ustorthents----	0-5	.10	.17	1	3	86
	5-11	.10	.15			
	11-36	.02	.10			
	36-61	---	---			
Blackash-----	0-8	.02	.02	5	1	220
	8-23	.02	.02			
	23-41	.02	.02			
	41-152	.02	.02			
Lava flows.						
29: Sunsetcrater-----	0-5	.02	.17	5	6	48
	5-20	.02	.10			
	20-46	.02	.05			
	46-81	.05	.24			
	81-152	.02	.10			
30: Sunsetcrater-----	0-5	.02	.17	5	6	48
	5-18	.02	.15			
	18-30	.02	.02			
	30-53	.10	.43			
	53-152	.02	.05			

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Table 24.—Total Soil Carbon

(This table displays soil organic carbon (SOC) and soil inorganic carbon (SIC) in kilograms per square meter to a depth of 2 meters or to the representative top depth of any kind of bedrock or any cemented soil horizon. SOC and SIC are reported on a volumetric whole soil basis, corrected for representative rock fragments indicated in the database. SOC is converted from horizon soil organic matter of the fraction of the soil less than 2 mm in diameter. If soil organic matter indicated in the database is NULL, SOC is assumed to be zero. SIC is converted from horizon calcium carbonate content fraction of the soil less than 2 mm in diameter. If horizon calcium carbonate indicated in the database is NULL, SIC is assumed to be zero. A weighted average of all horizons is used in the calculations. Only major components of a map unit are displayed in this table)

Map unit symbol, component name, and component percent	SOC	SIC
	kg/m ²	kg/m ²
20:		
Cinderhill (75%)-----	5	0
Blackash (25%)-----	7	0
21:		
Cinderhill (55%)-----	6	0
Kana'a (30%)-----	2	0
22:		
Cinderhill (65%)-----	5	2
Lava flows (15%)-----	0	0
23:		
Cumulic Haplustolls (100%)-----	7	0
24:		
Kana'a (90%)-----	3	0
25:		
Kana'a (80%)-----	2	0
Cinder land (20%)-----	0	0
26:		
Kana'a (65%)-----	2	0
Cinder land (35%)-----	0	0
27:		
Lava flows (80%)-----	0	0
Lithic Haplofibrists (20%)-----	1	0
28:		
Lithic Ustorthents (40%)-----	1	0
Blackash (35%)-----	7	0
Lava flows (25%)-----	0	0

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Table 24.—Total Soil Carbon—Continued

Map unit symbol, component name, and component percent	SOC	SIC
	<u>kg/m²</u>	<u>kg/m²</u>
29: Sunsetcrater (95%)-----	4	1
30: Sunsetcrater (100%)-----	3	0

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Table 25.—Soil Features

(See text for definitions of terms used in this table. Absence of an entry indicates that data were not populated. Components with no data in all columns will not display)

Map symbol and soil name	Restrictive layer			Potential for frost action	Risk of corrosion	
	Kind	Depth to top	Hardness		Uncoated steel	Concrete
		cm				
20: Cinderhill-----	---	---	---	Low	Moderate	Low
Blackash-----	---	---	---	Low	Moderate	Low
21: Cinderhill-----	---	---	---	Low	Moderate	Low
Kana'a-----	---	---	---	Low	Moderate	Low
22: Cinderhill-----	---	---	---	Low	Moderate	Low
23: Cumulic Haplustolls-	---	---	---	Moderate	Moderate	Low
24: Kana'a-----	---	---	---	Low	Moderate	Low
25: Kana'a-----	---	---	---	Low	Moderate	Low
26: Kana'a-----	---	---	---	Low	Moderate	Low
27: Lithic Haplofibrists	Lithic bedrock	5-10	Indurated	Moderate	High	Low
28: Lithic Ustorthents--	Lithic bedrock	5-36	Indurated	Low	Moderate	Low
Blackash-----	---	---	---	Low	Moderate	Low
29: Sunsetcrater-----	---	---	---	Low	Moderate	Low
30: Sunsetcrater-----	---	---	---	Low	Moderate	Low

Table 26.-Water Features

(See text for definitions of terms used in this table. Estimates of the frequency of ponding and flooding apply to the whole year rather than to individual months. Absence of an entry indicates that the feature is not a concern or that data were not estimated. Depth to water table is based on a representative value)

Map unit symbol and soil name	Hydro- logic group	Months	Water table		Surface water depth	Ponding		Flooding	
			Upper limit	Lower limit		Duration	Frequency	Duration	Frequency
			Ft	Ft	Ft				
20: Cinderhill-----	A	Jan-Dec	---	---	---	---	None	---	None
Blackash-----	A	Jan-Dec	---	---	---	---	None	---	None
21: Cinderhill-----	A	Jan-Dec	---	---	---	---	None	---	None
Kana'a-----	A	Jan-Dec	---	---	---	---	None	---	None
22: Cinderhill-----	A	Jan-Dec	---	---	---	---	None	---	None
Lava flows.									
23: Cumulic Haplustolls-----	B	January	---	---	---	---	None	---	Very rare
		February	---	---	---	---	None	---	Very rare
		March	---	---	---	---	None	---	Very rare
		April	---	---	---	---	None	---	Very rare
		May	---	---	---	---	None	---	Very rare
		June	---	---	---	---	None	---	Very rare
		July	---	---	---	---	None	Very brief	Rare
		August	---	---	---	---	None	Very brief	Rare
		September	---	---	---	---	None	Very brief	Rare
		October	---	---	---	---	None	---	Very rare
		November	---	---	---	---	None	---	Very rare
		December	---	---	---	---	None	---	Very rare
24: Kana'a-----	A	Jan-Dec	---	---	---	---	None	---	None

Table 26.-Water Features-Continued

Map unit symbol and soil name	Hydro- logic group	Months	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			<u>Ft</u>	<u>Ft</u>	<u>Ft</u>				
25: Kana'a-----	A	Jan-Dec	---	---	---	---	None	---	None
Cinder land.									
26: Kana'a-----	A	Jan-Dec	---	---	---	---	None	---	None
Cinder land.									
27: Lava flows.									
Lithic Haplofibrists-----	D	Jan-Dec	---	---	---	---	None	---	None
28: Lithic Ustorthents-----	D	Jan-Dec	---	---	---	---	None	---	None
Blackash-----	A	Jan-Dec	---	---	---	---	None	---	None
Lava flows.									
29: Sunsetcrater-----	B	Jan-Dec	---	---	---	---	None	---	None
30: Sunsetcrater-----	B	Jan-Dec	---	---	---	---	None	---	None

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Table 27.—Chemical Properties of the Soils

(Absence of an entry indicates that data were not estimated)

Map symbol and soil name	Depth	Cation- exchange capacity	Soil reaction	Calcium carbon- ate	Gypsum	Salinity	Sodium adsorp- tion ratio
	Cm	meq/100 g	pH	Pct	Pct	mmhos/cm	
20:							
Cinderhill-----	0-8	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	8-18	1.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	18-38	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	38-152	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
Blackash-----	0-5	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-18	1.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	18-41	1.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	41-152	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
21:							
Cinderhill-----	0-5	2.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-15	2.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	15-30	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	30-152	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
Kana'a-----	0-8	1.0-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	8-20	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	20-28	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	28-152	1.0-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
22:							
Cinderhill-----	0-5	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-18	1.0-4.0	6-7.8	0-2	0-2	0.0-2.0	0-2
	18-152	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
23:							
Cumulic Haplustolls--	0-5	9.0-14.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-20	9.0-14.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	20-38	9.0-14.0	6.6-8.4	0-2	0-2	0.0-2.0	0-2
	38-69	10.0-15.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	69-140	6.0-10.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	140-152	6.0-10.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
24:							
Kana'a-----	0-5	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-10	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	10-20	1.0-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	20-48	1.0-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	48-152	0.8-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
25:							
Kana'a-----	0-5	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-10	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	10-152	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
26:							
Kana'a-----	0-8	1.0-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	8-15	1.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	15-152	1.0-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
27:							
Lithic Haplofibrists-	0-8	8.0-11.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	8-10	8.0-11.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	10-35	---	---	---	---	---	---

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 27.—Chemical Properties of the Soils—Continued

Map symbol and soil name	Depth	Cation- exchange capacity	Soil reaction	Calcium carbon- ate	Gypsum	Salinity	Sodium adsorp- tion ratio
	Cm	meq/100 g	pH	Pct	Pct	mmhos/cm	
28:							
Lithic Ustorthents---	0-5	1.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-11	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	11-36	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	36-61	---	---	---	---	---	---
Blackash-----	0-8	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	8-23	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	23-41	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	41-152	1.0-4.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
29:							
Sunsetcrater-----	0-5	2.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-20	2.0-6.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	20-46	1.0-3.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	46-81	11.0-17.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	81-152	7.0-12.0	7.4-8.4	0-2	0-2	0.0-2.0	0-2
30:							
Sunsetcrater-----	0-5	2.0-7.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	5-18	2.0-7.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	18-30	1.0-5.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	30-53	12.0-17.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2
	53-152	2.0-7.0	6.6-7.8	0-2	0-2	0.0-2.0	0-2

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 28.—Taxonomic Classification of the Soils

(An asterisk in the first column indicates a taxadjunct to the series. See text for a description of those characteristics that are outside the range of the series)

Soil name	Family or higher taxonomic class
Blackash-----	Ashy, glassy, nonacid, frigid Vitrandic Ustorthents
Cinderhill-----	Ashy-skeletal, glassy, nonacid, frigid Vitrandic Ustorthents
Cumulic Haplustolls-----	Coarse-loamy, mixed, superactive, frigid Cumulic Haplustolls
Kana'a-----	Cindery, glassy, frigid Vitrandic Ustorthents
Lithic Haplofibrists-----	Euic, frigid Lithic Haplofibrists
Lithic Ustorthents-----	Ashy-skeletal, glassy, nonacid, frigid Lithic Ustorthents
*Sunsetcrater-----	Cindery, glassy, frigid Vitrandic Haplustepts
Sunsetcrater-----	Ashy-skeletal, glassy, frigid Vitrandic Haplustepts

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 29.—Soil Classification Key

(An asterisk indicates a taxadjunct to the series. See text for a description of those characteristics that are outside the range of the series)

ORDER
Suborder
Great Group
Subgroup
Series or Higher Category

ENTISOLS
Orthents
Ustorthents
Lithic Ustorthents
Lithic Ustorthents-----Ashy-skeletal, glassy, nonacid, frigid Lithic Ustorthents
Vitrandic Ustorthents
Blackash-----Ashy, glassy, nonacid, frigid Vitrandic Ustorthents
Cinderhill-----Ashy-skeletal, glassy, nonacid, frigid Vitrandic Ustorthents
Kana'a-----Cindery, glassy, frigid Vitrandic Ustorthents

HISTOSOLS
Fibrists
Haplofibrists
Lithic Haplofibrists
Lithic Haplofibrists-----Euic, frigid Lithic Haplofibrists

INCEPTISOLS
Ustepts
Haplustepts
Vitrandic Haplustepts
Sunsetcrater-----Ashy-skeletal, glassy, frigid Vitrandic Haplustepts
*Sunsetcrater-----Cindery, glassy, frigid Vitrandic Haplustepts

MOLLISOLS
Ustolls
Haplustolls
Cumulic Haplustolls
Cumulic Haplustolls-----Coarse-loamy, mixed, superactive, frigid Cumulic Haplustolls

Soil Survey of Sunset Crater Volcano National Monument, Arizona

Table 30.—Data on Lab-Sampled Pedons

Correlated name	Pedon type	Sampled as name	User site ID	Lab source*	Lab pedon number
Sunsetcrater	Modal pedon for series	Vitrandidic Haplustepts	SUCR-TUD010-MU1125	KSSL	12N02822

* KSSL indicates the Kellogg Soil Survey Laboratory in Lincoln, Nebraska.

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0 1 4 Kilometers
0 1 4 Miles



To Cameron, Grand Canyon, and Lake Powell

NAVAJO
INDIAN
RESERVATION

Box Canyon
dwellings



Nalakihi Pueblo



Citadel Pueblo



Lomaki Pueblo

WUPATKI NATIONAL MONUMENT

PRAIRIE
DONEY CLIFFS
WUPATKI
BASIN
ANTELOPE

Doney Mountain
5589ft
1703m



Wupatki Pueblo
0.5 mile loop trail

Visitor Center



4900ft
1493m

Wukoki Pueblo



WOODHOUSE MESA

89

15mi
24km

Deadman
Wash

LAVA
FLOW

Strawberry Crater

FOREST

COCONINO

NATIONAL

Loop Road
(35 mi/56 km)

O'Leary Peak
8916ft
2717m

Bonito
USDA Forest Service



SUNSET CRATER VOLCANO
NATIONAL MONUMENT

BONITO
LAVA
FLOW

Cinder Hills
Overlook

Sunset Crater
8039ft
2450m



Lenox Crater
Trail



Lenox Crater

Lava Flow Trail
1 mile loop trail



Painted Desert Vista



KANA-A
LAVA
FLOW

Visitor Center



6960ft
2121m

To Flagstaff

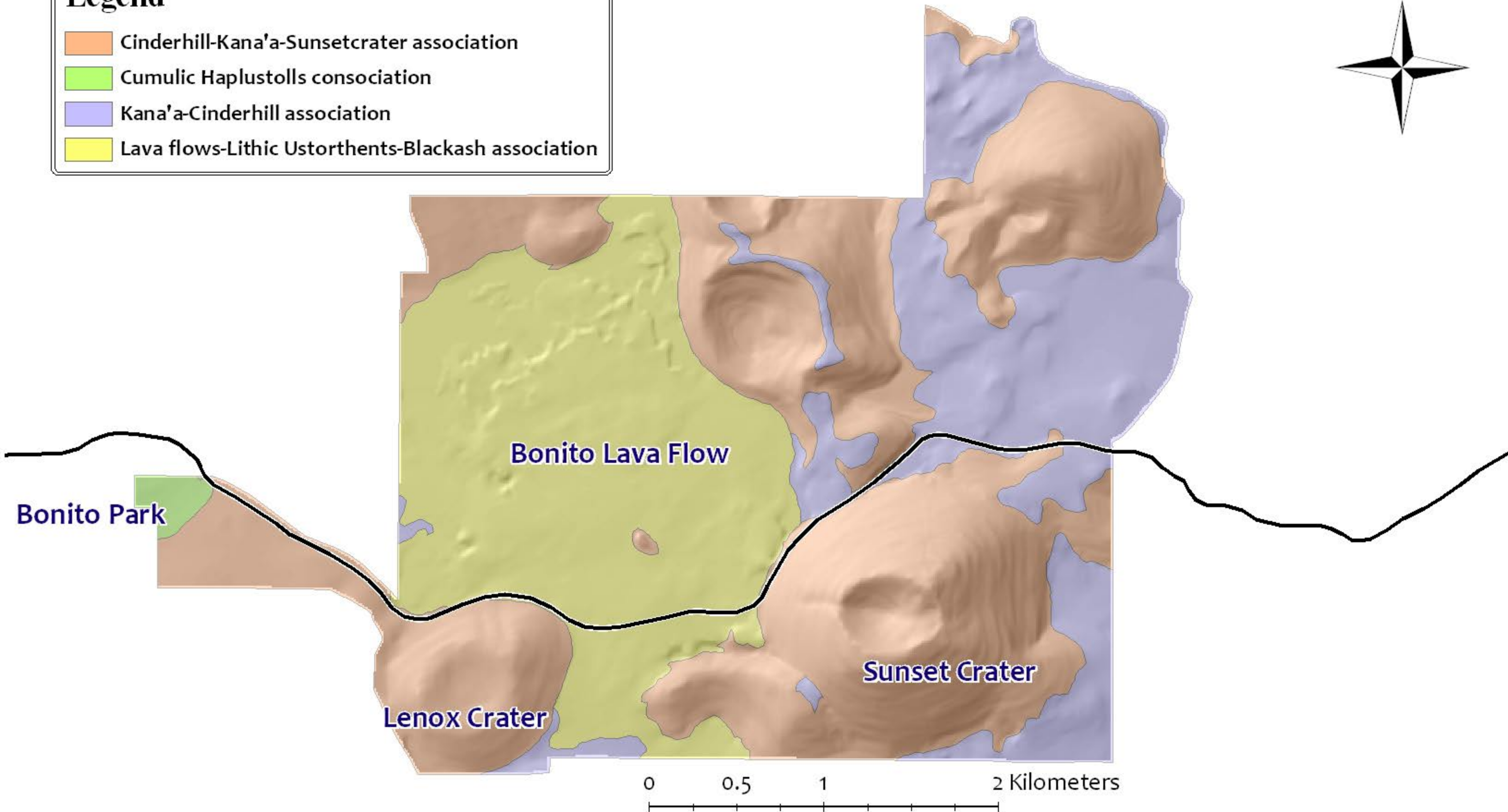
- Overlook or pullout
- Unpaved road (inquire locally for condition)
- Trail
- Lava flow

- Campground
- Picnic area
- Self-guiding trail
- Ranger station
- Restrooms

General Soils Map of Sunset Crater Volcano National Monument

Legend

- Cinderhill-Kana'a-Sunsetcrater association
- Cumulic Haplustolls consociation
- Kana'a-Cinderhill association
- Lava flows-Lithic Ustorthents-Blackash association



U.S. DEPARTMENT OF
AGRICULTURE

NATURAL RESOURCES
CONSERVATION SERVICE

MAP UNIT LEGEND
SUNSET CRATER VOLCANO NATIONAL
MONUMENT, ARIZONA

U.S. DEPARTMENT
OF THE INTERIOR

NATIONAL PARK
SERVICE

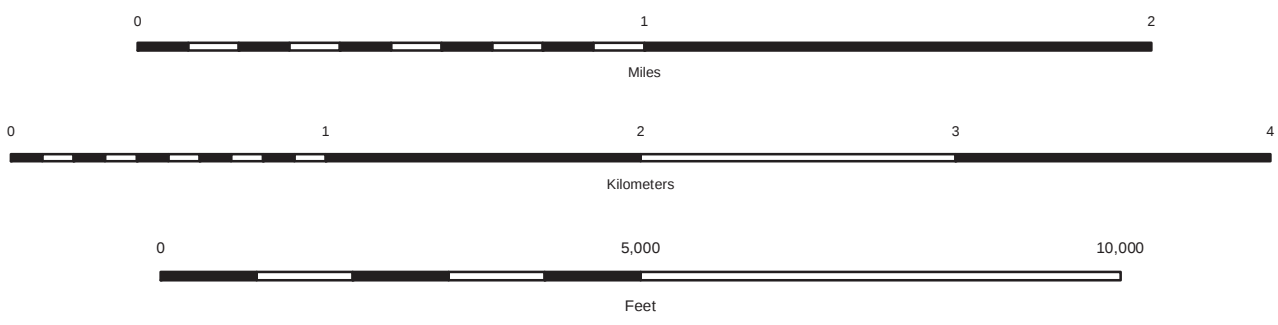
SYMBOL

NAME

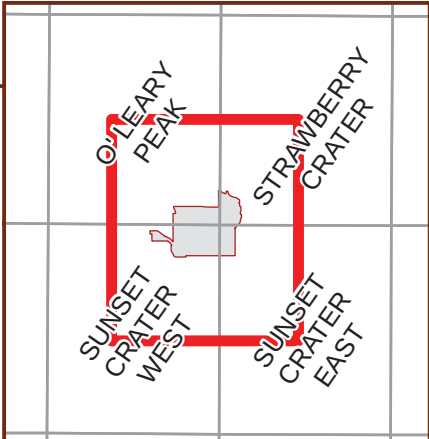
- | | |
|----|--|
| 20 | Cinderhill-Blackash complex, 15 to 60 percent slopes |
| 21 | Cinderhill-Kana`a complex, 3 to 15 percent slopes |
| 22 | Cinderhill-Lava flows complex, 2 to 15 percent slopes |
| 23 | Cumulic Haplustolls extremely gravelly sandy loam, 0 to 2 percent slopes |
| 24 | Kana`a extremely gravelly sand, 1 to 3 percent slopes |
| 25 | Kana`a-Cinder land complex, 1 to 15 percent slopes |
| 26 | Kana`a-Cinder land complex, 15 to 60 percent slopes |
| 27 | Lava flows-Lithic Haplofibrists complex, 2 to 15 percent slopes |
| 28 | Lithic Ustorthents-Blackash-Lava flows complex, 2 to 15 percent slopes |
| 29 | Sunsetcrater extremely gravelly loamy sand, 1 to 15 percent slopes |
| 30 | Sunsetcrater extremely gravelly loamy sand, 15 to 35 percent slopes |



This soil survey was compiled by the U.S. Department of Agriculture, Natural Resources Conservation Service, at the request of the U.S. Department of the Interior, National Park Service. Base maps are orthophotographs prepared by the U.S. Department of Agriculture, Farm Service Agency, from 2010 aerial photography. Cultural information was acquired from USGS topo maps and other sources. Hydro information was derived from USGS topo maps and orthophotography. Park Boundary information was obtained from the National Park Service in 2010. Shaded relief background was created from 10 meter NED elevation data from USDA/NRCS. Soil information for the Sunset Crater Volcano National Monument area was derived from the USDA/NRCS Soil Survey Geographic (SSURGO) database for Oak Creek - San Francisco Peaks Area, Arizona, Part of Coconino County (AZ603), mapped October, 2012. North American Datum of 1983 (NAD83), GRS80 Spheroid, Universal Transverse Mercator, zone 12. Coordinate ticks and land division data, if shown, are approximately positioned. Digital data are available for this area.



INDEX TO ADJOINING
7.5 MINUTE MAP SHEETS

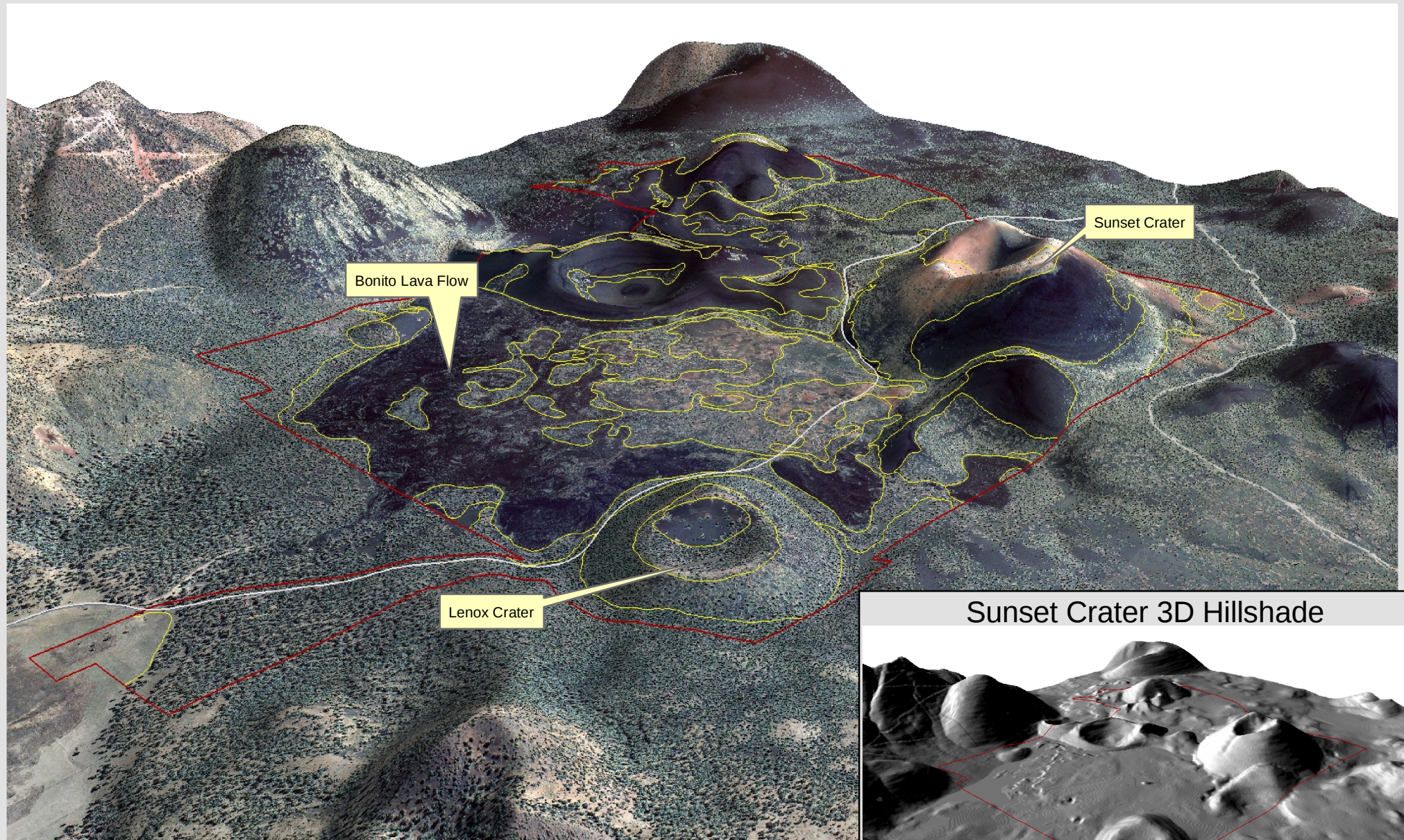


PARTS OF O'LEARY PEAK,
STRAWBERRY CRATER,
SUNSET CRATER WEST,
AND SUNSET CRATER EAST
QUADRANGLES

SHEET NUMBER 1 OF 1

SOIL SURVEY OF
SUNSET CRATER VOLCANO
NATIONAL MONUMENT

Sunset Crater Volcano National Monument 3D Map

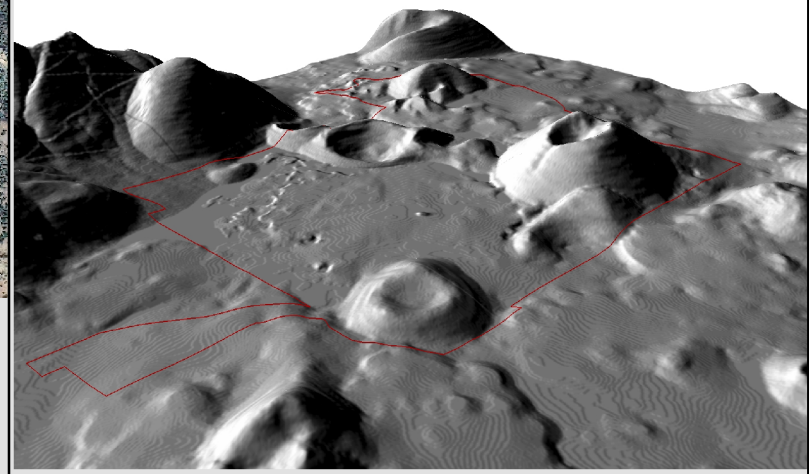


Legend

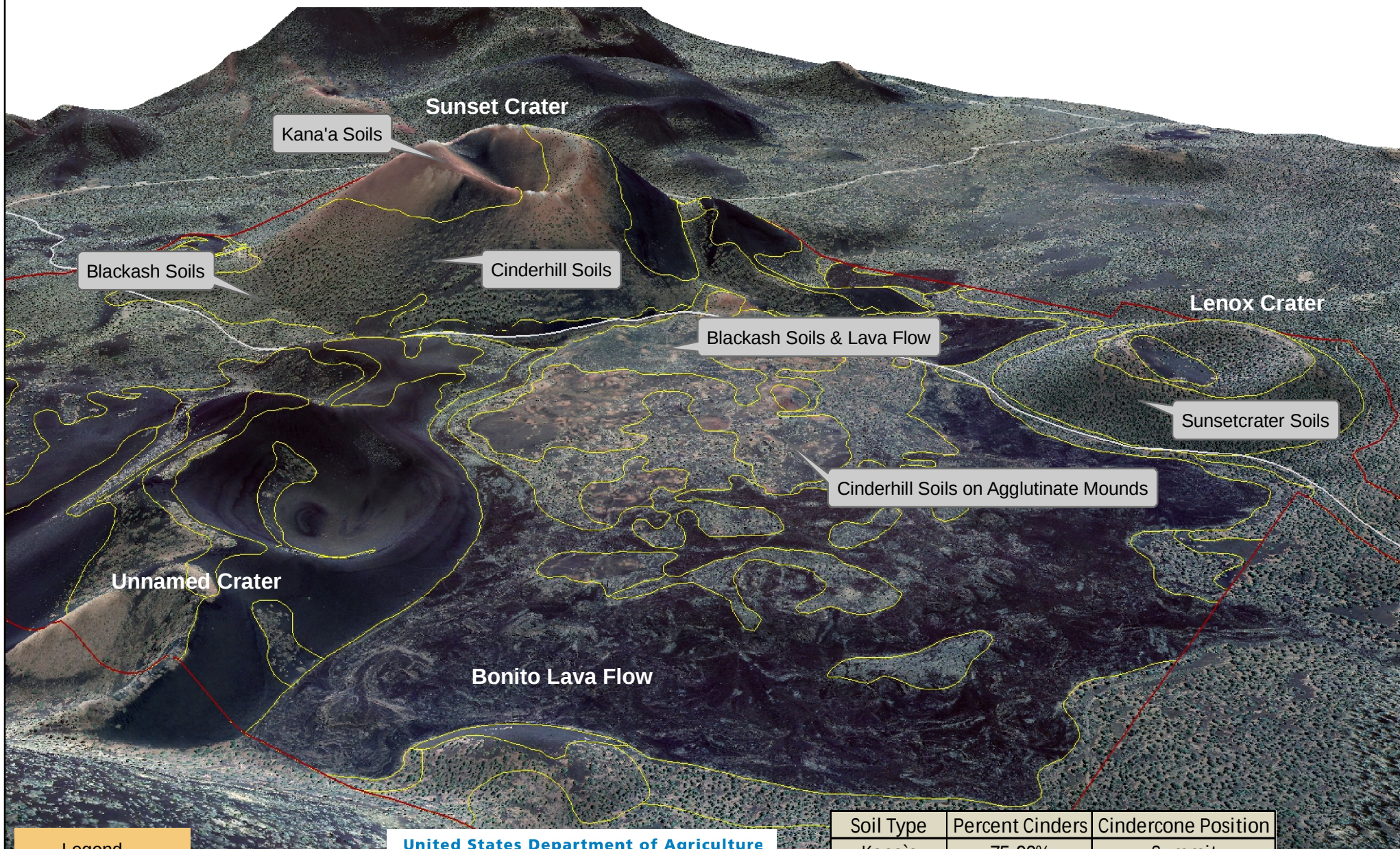
- Park Boundary
- Soil Map Units
- Roads



Sunset Crater 3D Hillshade



Sunset Crater Volcano National Monument 3D Soil Types



Legend

- Park Boundary
- Soil Map Units
- Roads



Soil Type	Percent Cinders	Cindercone Position
Kana`a	75-90%	Summit
Sunsetcrater	35-80%	Backslope
Cinderhill	35-75%	Backslope
Blackash	20-35%	Footslope